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## **Morphological Changes on the Axillary Border of the Scapula with Special Reference to the Neandertal Problem**

Carol Baratz Dittner-Plasil  
*University of Tennessee, Knoxville*

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Fred H. Smith, Major Professor

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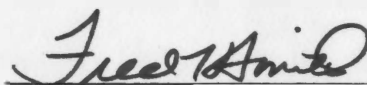
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MORPHOLOGICAL CHANGES ON THE AXILLARY BORDER OF THE SCAPULA

WITH SPECIAL REFERENCE TO THE NEANDERTAL PROBLEM

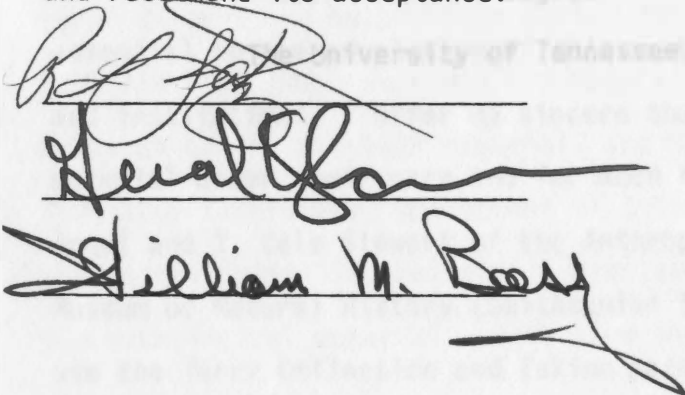
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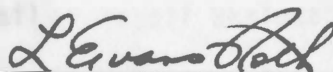


Fred H. Smith, Major Professor

We have read this dissertation  
and recommend its acceptance:



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Vice Chancellor

Graduate Studies and Research

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X

MORPHOLOGICAL CHANGES ON THE AXILLARY BORDER OF THE SCAPULA  
WITH SPECIAL REFERENCE TO THE NEANDERTAL PROBLEM

A Dissertation  
Presented for the  
Doctor of Philosophy  
Degree  
The University of Tennessee, Knoxville

Carol Baratz Dittner-Plasil

March 1981

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## ABSTRACT

This study is an effort to determine the causes of the various morphologies of the axillary border of the modern human scapula and to relate the results to the unusual morphology of Neandertal scapulae.

Two-thirds of known Neandertal scapulae exhibit a dorsal sulcus on the axillary border: the remainder have a double sulcus (Chancelade pattern) and only one exhibits a ventral sulcus. The ventral sulcus is predominant on the scapulae of anatomically modern hominids where the Chancelade pattern is also present in varying frequencies.

Quantitative and qualitative analyses were performed on data derived from skeletal material of five modern human groups in order to determine the causes of morphological changes on the axillary border of the scapula. The groups are: blacks and whites from a documented hospital collection (Terry Collection); Alaskan Eskimos; Southeastern American Indians of the Mississippian period, and of the Archaic period. The groups varied with respect to race, time and technological level.

Greater frequencies of the Chancelade pattern were found with advancing age and on the right side in these groups. It is suggested that, in modern humans, increased muscular stress, resulting from increased use of the upper limb, promotes greater development of the teres minor muscle as seen in the Chancelade morphology. Additionally, in modern hominids, the Chancelade pattern is positively associated with more curved clavicles (indicating a slightly rounder thorax) and with more cranially deviated humeral heads. Thus, it is further

suggested that the rounder thorax of Neandertals may have caused their scapulohumeral-musculoskeletal relationships to be different from those of modern hominids. This effect together with the more strenuous use of the upper limbs (due to greater demands of the cultural level) may have caused enlargement of the teres minor muscle, thus creating a dorsal sulcus on most Neandertal scapulae.

Other factors contributing to the morphological changes from Neandertals to modern hominids may have been cultural changes which produced differences in tool and weapon handling, and/or genetic selection.

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## CHAPTER I

### INTRODUCTION

#### I. INTRODUCTION TO THE PROBLEM

The first Neandertal specimen was recognized in 1856. There is still not total agreement among human paleontologists over the significance in human ancestry for this and related specimens. At first the specimen from the Neander valley in Germany was considered to be a human deviant with ape-like qualities. As other related specimens were discovered, the finds were reconsidered and the specimens were given three interpretations. Some believed them to represent pathological modern humans; others felt they were a primitive group of modern men; and still others considered them an extinct species, Homo neanderthalensis. Today the specimens are considered a distinct subspecies of Homo sapiens, Homo sapiens neanderthalensis, or, by some workers as simply "archaic" Homo sapiens. Most studies on Neandertals have concentrated on features of the Neandertal cranium (Howell 1957, Brace 1964, Brose and Wolpoff 1971, Howells 1973). However, there are limited investigations dealing with the Neandertal postcranial skeleton, even though it exhibits certain unique or unusual morphological features compared with Homo sapiens sapiens. The purpose of this study is to investigate one of the more interesting postcranial characteristics of Neandertals, the form of the axillary border of the scapula (von Eickstedt 1925, Vallois 1932, McCown and Keith 1939, Stewart 1962a, Smith 1976b, Dittner 1976, Trinkaus 1977b).

Originally, the term "Neandertal" designated only the type specimen found near Dusseldorf, Germany. Currently the term has been extended by some workers to include fossil specimens found in Europe, Western and Eastern Asia, South and East Africa, and Java and dating from approximately 150,000 (or earlier) to 35,000 years ago. For the purpose of this work, the terms "Classic Neandertal" or "Western European Neandertal" will be applied exclusively to the specimens found in Western Europe during Würm I and II (Le Gros Clark 1978). The terms "Neandertal" or "archaic Homo sapiens" will be used in a more general sense and will refer to skeletal material of this period from all of Europe, as well as from western Asia.

There are three existing major hypotheses regarding the relationship between Neandertal and modern humans. Boule (1921) and his student Vallois (1958), lead the "pre-Sapiens" school which promotes the hypothesis that all Neandertals were the end-product of a completely separate side branch of hominid evolution coexisting with, but independent of, that branch leading to modern Homo sapiens. This school maintains that the roots of the modern Homo sapiens lineage began with the Swanscombe specimen from the Holstein Interglacial.

A second school of thought, the pre-Neandertal school, interprets the remains from Swanscombe and Steinheim as the progenitors of a Generalized or Progressive type of Neandertal found during the Eemian Interglacial in Europe and the Near East. These Generalized Neandertals supposedly developed into modern hominids outside of Europe, and into Classic Neandertals in Western Europe where they were isolated and cold-adapted. Supporters of the pre-Neandertal hypothesis believe that modern Homo sapiens then moved into Europe (most likely from the Near

East), either completely replacing or partially absorbing the indigenous populations. F. C. Howell (1951, 1952, 1957), W. W. Howells (1973, 1974, 1976), W. E. Le Gros Clark (1978), and Trinkaus and Howells (1979) are leading proponents of the pre-Neandertal theory.

The in situ evolution from Neandertal into early modern hominids in Europe and the Near East is the hypothesis espoused by the Unilineal or Neandertal school. First proposed by Schwalbe (1906) and later propagated by Hrdlička (1927) and Weidenreich (1947), this theory has been revived by Brace (1962, 1964, 1967), Brose and Wolpoff (1971), Smith (1976b), and Wolpoff (1980). These scholars believe that cold-adaptation and vise-like use of the teeth contributed to the robustness of the Neandertal face. Subsequent cultural development replaced biological adaptation and accounts for the decrease in robusticity of the face. As there is no earlier evidence from the Near East of modern Homo sapiens, the Unilinealists believe that a direct and gradual transition between Neandertals and early modern man in Europe is the most logical and supportive explanation in light of present data. The evolutionary influence exerted by an influx of modern hominids is not necessary to explain this transition.

Among the problems that contributed to the dilemma of Neandertal's place in our ancestry has been the paucity of significant hominid material from the crucial time period of the early phases of the Upper Paleolithic. However, re-examination of old material in the light of new dates and of a better understanding of skeletal biological variability may yield new insights into the problem.

The frontal bone from Velika Pečina, dating to  $33,850 \pm 520$  B.P. (Smith 1976a) and the establishment of early dates for Předmostí,

Mladeč, Brno, and others of the early Upper Paleolithic (Jelinek 1969) help to fill some chronological and geographical gaps in the fossil record. Material discovered at relatively well-dated sites with good archaeological association exhibit a mixture of Neandertal and more modern morphology. Morphological transition between the Neandertal and the modern type is exhibited by specimens at Kůlna, Šipka, and Vindija (Jelinek 1967, 1976; Malez et al. 1980; Wolpoff et al., in press). Transitional specimens such as these have been found in association with archaeological material which is predominately Mousterian, yet bears elements of Upper Paleolithic cultures (Jelinek 1976). There is diminishing evidence of cultural discontinuity and "sudden" replacement of the Mousterian culture by the Upper Paleolithic tradition (Valoch 1968, Brose and Wolpoff 1971). Archaeological as well as skeletal data are beginning to yield evidence of the "slow cultural change of the Middle Paleolithic Mousterian into . . . the Upper Paleolithic" (Mann and Trinkaus 1973:188). While definitive information is still lacking, the cultural and biological boundary between Neandertals and modern hominids in Europe appears to be deteriorating.

In the past there were several misconceptions concerning the image of Neandertals. Boule's notable study of the La Chapelle-aux-Saints postcranial and cranial remains (1911/13), which contributed greatly to the idea of morphological gaps between Neandertals and modern hominids, is now known to be false. The fragmentary nature of part of the skeleton, improper reconstruction and the failure to recognize the pathological aspects of the specimen, led to Boule's misinterpretation. Straus and Cave (1957) found no evidence, for example, that Neandertal spinal columns lacked the convexities necessary for fully erect posture.

Further, they pointed out that deforming arthritis of the spine and foot made this specimen a poor one from which to interpret Neandertal posture. In addition, Stewart (1962b) concluded from his studies of Neandertal cervical vertebrae that there was no basis for Boule's contention that Neandertal man's head was slung forward on a short and thick neck.

The postcranial remains of the Classic and other Neandertals are now considered to be essentially like those of modern hominids except for greater robusticity (Howell 1957; Musgrave 1971, 1973; Trinkaus 1975b; Rhoads and Trinkaus 1977). Neandertal feet (Trinkaus 1975a) and ankles (Rhoads and Trinkaus 1977) reflect heavy biomechanical stress on the joint surfaces and in muscle attachment areas. Patterns of stress are reflected in the huge robusticity indices, especially of the tibial shafts, the metatarsals and proximal phalanges (Trinkaus 1975a,b; Rhoads and Trinkaus 1977; Trinkaus and Stewart, in press). Bowing occurs in many Neandertal upper and lower limb bones (McCown and Keith 1939) and is considered a product of stressful use (Riesenfeld 1966; Trinkaus 1975a, 1976; Rhoads and Trinkaus 1977). The total morphological pattern and functioning of Neandertal feet and lower limbs, however, is, as in all Neandertal postcranials, within the ranges of anatomically modern man (Trinkaus 1978b, Trinkaus and Stewart, in press).

The greater transverse width of the heads of thumb metacarpals and the relatively short length of distal phalanges demonstrate that the Neandertal hand was a squat, powerful unit (Musgrave 1971, 1973). These distinguishing features of the Neandertal hand do occur in

modern man, but are rarely found in combination in one hand (Musgrave 1971).

Neandertal humeri exhibit robustness in their massive articular ends and the diameter of the shaft. The tendency of the humeral heads is to be more cranially directed and to have greater width than those of modern humans (McCown and Keith 1939). The Neandertal ribs differ from those of modern human's in thickness, curvature, and their more horizontal position (Hrdlička 1930, McCown and Keith 1939, Coon 1962, Endo and Kimura 1970, Smith 1976b). In accord with this morphological pattern of the ribs, the clavicles of Neandertals are typically more strongly curved than is usual in modern humans (Hrdlička 1930, McCown and Keith 1939, Smith 1976b). These features suggest that the Neandertal thorax was barrel-shaped (Hrdlička 1930, McCown and Keith 1939). "This barrel-chested concept of Neandertals . . . is consistent with the data from the clavicle and fits well the robust total morphological pattern of Neandertals" (Smith 1976b:291). Despite these differences, Neandertal postcranial remains are "not morphologically or functionally different from (those) of modern man". (Le Gros Clark 1978:64).

There are two postcranial areas, however, where the anatomical features of Neandertals are outside the range of variation for modern hominids. One area is in the thinning and elongation of the superior pubic ramus of the innominate. McCown and Keith (1939) first noticed this peculiar morphology on the pelvis of the Tabūn woman of Mount Carmel. It appeared to distinguish her from the Skhūl population, as well as from that of modern hominids. Stewart (1960) also reported this peculiar thinning and elongation of the superior pubic rami in

Shanidar I and III. As both of these Shanidar specimens appear to be males, it was concluded that the peculiarity was probably not due to sexual differences. Amud I, another male, also exhibits this morphology (Endo and Kimura 1970).

This thinning and elongation of the superior pubic ramus was recently studied in the remains of the La Ferrassie I and Krapina 208 innominates, and compared to the previously studied Southwest Asian Neandertals (Trinkaus 1976). It appears that the supero-inferior flattening of the ramus is a secondary result of the elongation of the ramus from acetabulum to symphysis. Both features are more pronounced among the Southwest Asian Neandertals than among the European Neandertals. Although there is greater elongation of pubic bones in modern females than in modern males (Bass 1971), the sampling of Neandertals available is thought to be of both sexes. This idea of sexual differences as well as the possibility of biomechanical alterations, e.g., hypertrophy and/or atrophy, has been investigated by Trinkaus (1976). The elongation and thinning of the pubis may be a consequence of the relative expansion of the cranium of Neandertals (at birth, as well as in adults) without commensurate change in average body size (Smith 1976b, Wolpoff 1980).

The second exceptional skeletal area of Neandertals is the morphology of the axillary border of the scapula. It has been noted by several workers (von Eickstedt 1925, Vallois 1932, McCown and Keith 1939, Stewart 1962a, Endo and Kimura 1970, Smith 1976b) that the axillary border of the scapulae of Neandertals normally exhibits a different morphological pattern than is usually exhibited in modern hominids.

### The Modern Type

Looking at the axillary border of the scapula of modern humans in its lateral aspect, one sees that a crest normally descends from behind and below the infraglenoid tubercle caudally toward the inferior angle (Figure 1B). In most modern hominids, a groove is formed ventrally when the crest, which extends from behind and below the infraglenoid tubercle, descends on the dorso-lateral aspect of the border. A longitudinal buttress or bar of bone rises on the ventral portion of the border which forms the ventral lip of the groove. In this type a gutter is formed on the ventral aspect of the border.

This gutter extends caudally for two-thirds of the border and deviates dorsally several millimeters before the teres process, where it ends. The groove is most often called simply the ventral groove or gutter, but may be called sulcus ventro-axillaris (Gorjanović-Kramberger 1914, Stewart 1962a), sulcus axillaris subscapularis (von Eickstedt 1925) or facies ventro-axillaris (Vallois 1932).

### The Neandertal Type

In many Neandertal scapulae (Figures 2 and 3B), the axillary crest veers off to join with the ventral buttress of the axillary border, thus forming a pronounced groove on the dorsal aspect of the bone, the exact opposite of the "modern" pattern. A bar or buttress of bone rises longitudinally on the dorsal aspect of the border forming the medial limit of this axillary gutter or groove. The groove and the buttressing pillars extend two-thirds of the length of the axillary border ending at the dorso-ventral flattened area of the teres process or protuberance. Boule first described this typical Neandertal type

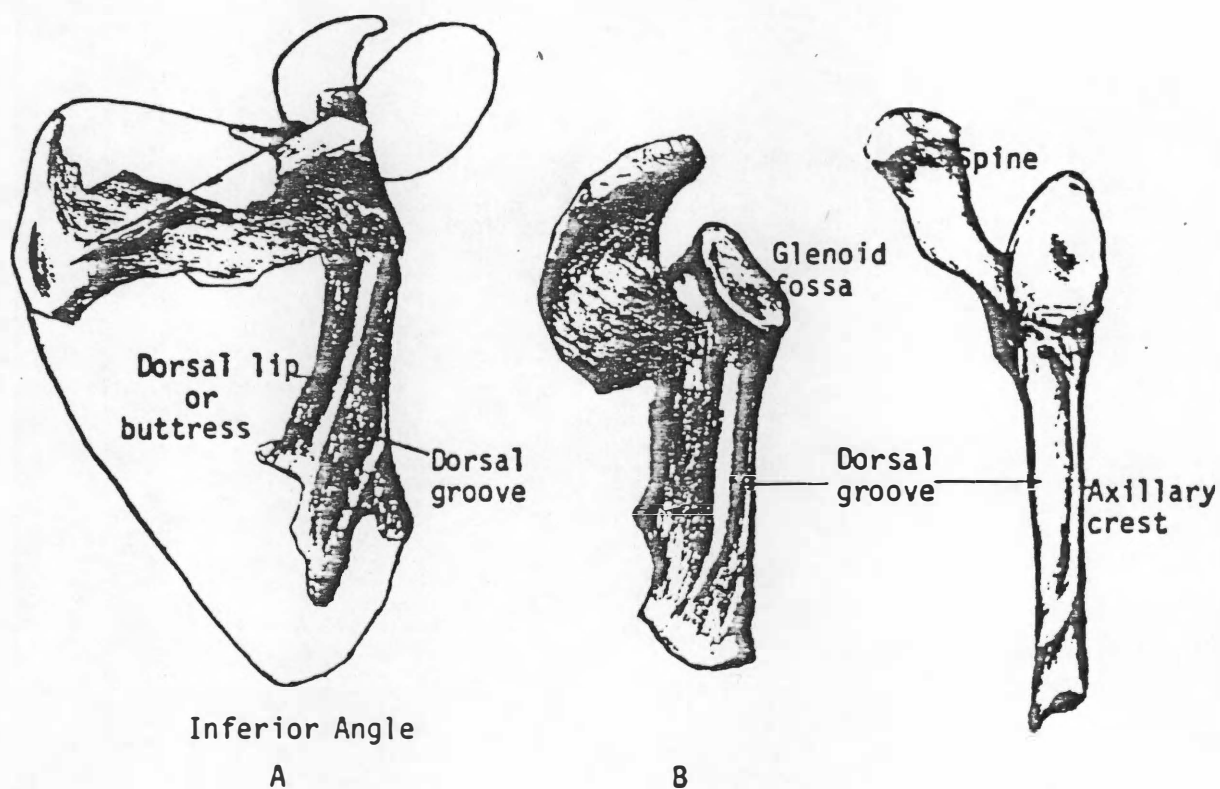


Figure 2. Right scapulae of La Ferrassie I (A) and of the original Neandertal from Dusseldorf (B) in dorsal-lateral views (left to right). Both scapulae have the *sulcus dorso-axillaris* or the Neandertal type border. From Stewart (1962a, Figures 3 and 4).

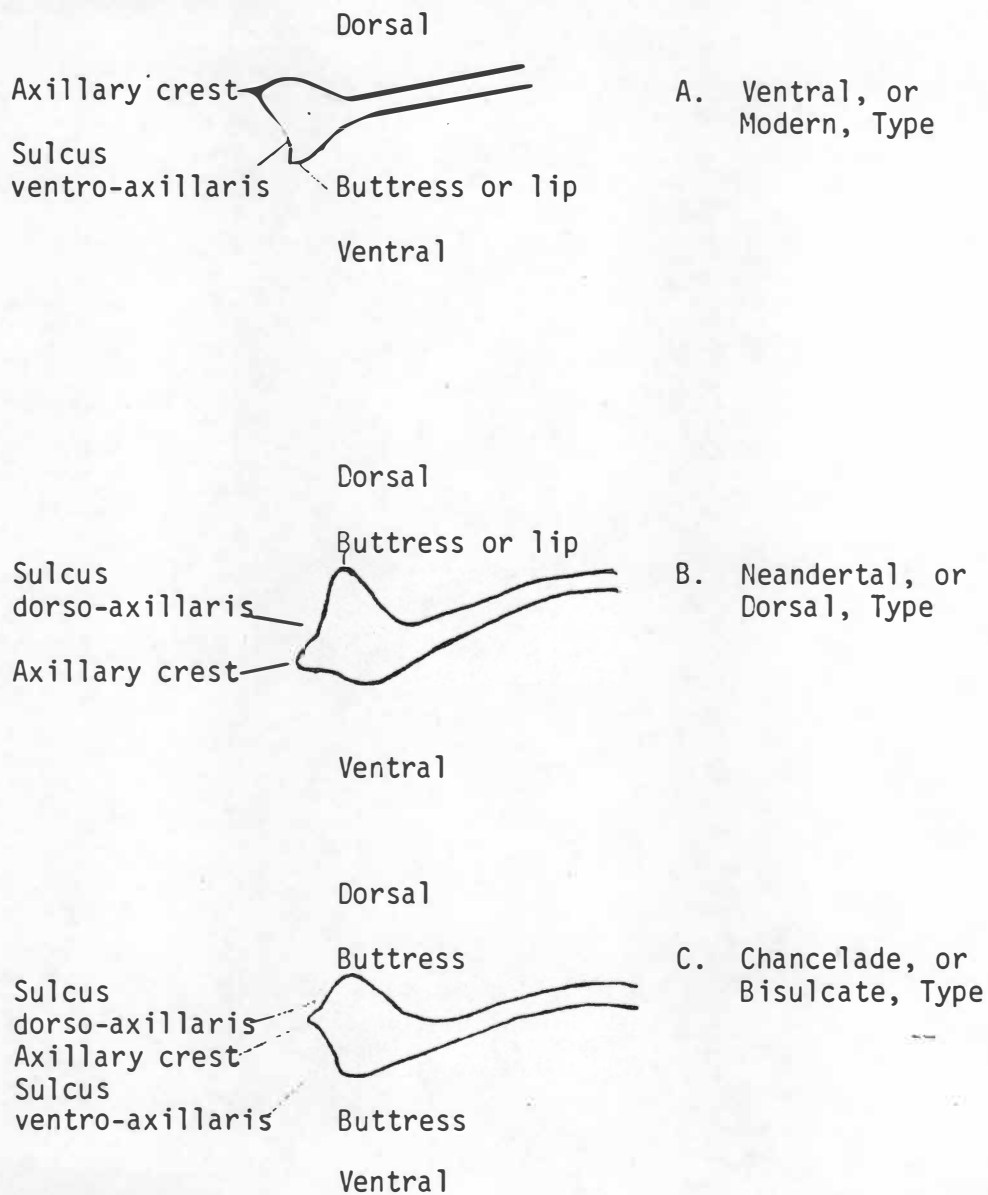


Figure 3. Schematic drawings of cross-sections of the three major types of axillary borders of the scapula. Revised from McCown and Keith 1939.

of axillary groove on the La Ferrassie I scapulae (Boule 1911/13). Von Eickstedt (1925) named this dorsal groove sulcus axillaris teretis in recognition of the dorsal muscular insertion. It is also called Boule's sulcus, sulcus dorso-axillaris (Gorjanović-Kramberger 1914), the Neandertal type (Stewart 1962a) or facies dorso-axillaris (Vallois 1932).

### The Chancelade Type

A third major variation of the axillary border was first described by Testut (1889) who noted this morphology on an Upper Paleolithic scapula from Chancelade. The Chancelade type, as it is often called (Figure 1A and Figure 3C), has two shallow, narrow, longitudinal grooves. In this type the crest that extends below the infraglenoid tubercle descends toward the center of the border rather than joining either the dorsal or ventral pillar or buttress. Most often, the sulcus nearer the ventral side is the larger one. In addition to the Chancelade type, this border may be called the bisulcate type (Trinkaus 1977b), or facies axillaris bisulcata (von Eickstedt 1925), as well as an intermediate type of scapular border. Greatest frequencies of the Chancelade type appear on Upper Paleolithic specimens. This type also occurs commonly in both modern humans and Neandertals (Stewart 1962a).

## II. STATEMENT OF THE PROBLEM

From the printed literature, personal communications and personal observation, it was determined that Neandertals display a distinct dorsal groove in two-thirds of the known specimens which

preserve this border (Table I). The Chancelade type, wherein two shallower, narrower, longitudinal sulci lie laterally on the border, is seen in approximately one-third of Neandertal scapulae (McCown and Keith 1939, Stewart 1962a, Endo and Kimura 1970, Smith 1976b, Trinkaus 1977b). Only one adult Neandertal specimen clearly exhibits a ventral groove on the border (Trinkaus 1977b, Smith 1978b). An indistinct groove pattern is found on the axillary border of Neandertal juveniles (Gorjanović-Kramberger 1926, Smith 1976b) which are not being considered in this analysis. (Indistinct morphology is generally the case in modern juveniles as well.)

This study tests the hypothesis that morphological differences on the axillary border of the scapula are at least partially a function of use. A secondary hypothesis tested is that the shape of the chest influences the morphology of the axillary border. It is additionally proposed that variable proportions of the scapula and humerus may combine to influence border morphology. Morphological and metrical data taken from various modern populations are employed in an attempt to determine the factors which influence the axillary border morphology. The ultimate goal of the study is to suggest a functional interpretation of the Neandertal morphology and of the modern morphology; and to suggest why morphological changes occurred on the axillary border between Neandertal and modern man.

Data gathered for this study were analyzed for the following information:

1. The frequency of occurrence of the various morphological types on the axillary border of the scapula in the modern samples.

TABLE I  
CLASSIFICATION OF SPECIMENS OF NEANDERTAL SCAPULAE  
WHICH PRESERVE THE AXILLARY BORDER

Specimen	Side	Reference for Morphological Determination
<u>Neandertal Type Axillary Border</u>		
Dusseldorf	Right	Boule 1911/13
La Ferrassie I	Right & Left	Boule 1911/13
La Ferrassie II	Left	Boule 1911/13
Shanidar I	Left	Stewart 1962a*
Shanidar II	Left	Trinkaus (personal communication)
Shanidar IV	Right	Stewart 1977
Tabun I	Left	McCown and Keith 1939
Spy I & II	Left & Right	Vallois 1932 (Serie 8)**
Amud I	Left	Endo and Kimura 1970
Krapina IX	Right	Gorjanović-Kramberger 1926
Krapina XI	Left	Gorjanović-Kramberger 1926
Krapina XII	Right	Gorjanović-Kramberger 1926--Smith (1976b) reclassified it as dorsal
Krapina V	Left	Wolpoff et al., in press
<u>Chancelade Type Axillary Border</u>		
Shanidar III	Right	Stewart 1962a
Krapina VII	Right	Gorjanović-Kramberger 1914
Krapina VIII	Right	Gorjanović-Kramberger 1914
Krapina X	Left	Gorjanović-Kramberger 1926
Krapina XIII	Right	Gorjanović-Kramberger 1926
Krapina XIV	Right	Gorjanović-Kramberger 1926
Krapina XV	Right	Gorjanović-Kramberger 1926
Krapina XIX	Left	Gorjanović-Kramberger 1926 "Possible" Chancelade type--Smith 1976b
<u>Ventral Type Axillary Border</u>		
Krapina VI	Right	Gorjanović-Kramberger 1914, Trinkaus 1977b, Smith 1978b

\*Shanidar I(R) may have beginning of dorsal groove (Stewart 1962a).

\*\*Hrdlička (1930) believed both left and right belong to Spy II.

2. The changes in frequencies of the morphological types with regard to:

- a. Age
- b. Sex
- c. Side

The data were examined with regard to side to determine whether a particular morphology appeared with greater frequency on one side when right and left scapulae were morphologically different. An assumption is that greater use of one hand and arm (handedness) influences morphology because of greater muscular exertion on that side. Handedness in the skeletal material is generally determined by noting which humerus, when both right and left are present, is longer or thicker (Hrdlička 1932, 1942c; Schultz 1930). When humeri were lacking, handedness was established by noting which scapula had the greater width on the axillary border (Vallois 1932).

If statistical analysis of the data reveals significant results for the factors investigated, it might be inferred that there is an ontogenetic or functional basis to the appearance of certain morphologies on the axillary border of the scapula. It is well known that bone in general responds to biomechanical stress by remodelling (Tschantz and Rutishauser 1967). The scapula, particularly, "is suspended . . . in space by the muscles acting upon it, . . . therefore, . . . this bone reflect(s) more clearly than any other the changes which have been brought about by more specialized functional demands" (Inman, Saunders and Abbott 1944:2). Additionally, the scapula is "subject to changes with age, most of which are brought

about, or are largely influenced by, muscular development and activity" (Hrdlička 1942c:413).

The scapula is only one part of the shoulder area and is being acted upon by muscles and related skeletal parts (Riesenfeld 1966). It is "a product of the muscles that radiate from it towards the spine, neck, chest and shoulder" (Hrdlička 1942a:73). Furthermore, the shoulder girdle, comprised of scapula, clavicle and humerus, should be studied as an integrated, functional complex which makes a variety of types of locomotion possible. One can probably define the stress patterns and infer the habitual patterns of use (Corruccini and Ciochon 1976). With this in mind, some differing tendencies of the Neandertal shoulder area were investigated here with regard to their possible effects on the axillary border.

There are several features in the shoulder area that have differing tendencies in Neandertal and modern humans. An attempt was made to synthesize the salient divergent features, while visualizing the interrelationships of the shoulder area, and thus to extract the reasons for the morphological changes on the axillary border of the scapula.

Different tendencies of Neandertal and modern hominids in the shoulder area and thorax include the following:

1. The rib cage of Neandertals tends to be different in shape from modern hominids. As previously described, Neandertals are more barrel-chested than modern humans. The thorax of Neandertals is more capacious than that of recent man as the ribs are less curved (Hrdlička 1930, McCown and Keith 1939, Endo and Kimura 1970, Wolpoff 1980). The shape of the thorax can be determined by the degree of curvature of

the clavicle (Hrdlička 1930, McCown and Keith 1939, Smith 1976b). The Homo erectus clavicle, represented by a specimen from Choukoutien, shows a high degree of curvature, similar to that of Krapina and the original Neandertal specimen (Weidenreich 1941). Unfortunately, there are no scapular remains of the Homo erectus grade.

2. Scapular index, the ratio of scapular breadth to the maximum length of the humerus, and of axillary border length to scapular height are slightly different in Neandertals compared to modern humans (McCown and Keith 1939; Trinkaus, personal communication concerning latter two ratios).
3. The humeral head of Neandertals is slightly more cranially directed (relative to the axis of the shaft) than that of modern humans. The humeral head of Neandertals is larger in transverse measurement than in vertical measurement (McCown and Keith 1939). In modern humans, the vertical measurement is normally greater than the transverse.

The hypothesis for these variations in the shoulder girdle is that scapulo-humeral relationships differed in the Neandertals because of the barrel-shaped chest. The altered relationships between scapula and humerus may have caused greater stress to be exerted on the teres minor muscle in Neandertals than in modern hominids, thus causing the enlargement of its attachment area on Neandertal scapulae (Dittner 1978). The teres minor muscle insertion forms a pronounced groove on the axillary borders of many Neandertal scapulae. This pronounced dorsal insertion is rarely seen on the borders of modern scapulae,

where a pronounced groove formed by the ventrally inserted subscapularis muscle is the common pattern. The Chancelade pattern with its two grooves appears to be morphologically intermediate between the Neandertal (dorsal) and the modern (ventral) patterns. This morphological pattern also appears to be temporally intermediate. It is seen on one-third of Neandertal scapulae, nearly all Upper Paleolithic scapulae, and in varying frequencies on modern scapulae. Because the Chancelade pattern is found with reasonable frequency in modern populations, it provides the means of studying quantitatively the relationship between the morphologies and anatomical relationships.

The data found in the sample skeletal material are used to test the hypotheses that differing scapulohumeral relationships and scapular proportions influence border morphologies, by determining the following correlations:

1. Is there a significant relationship in the modern samples used here between the Chancelade bordered scapulae and more curved clavicles or higher clavicular/humeral ratios [clavicular/humeral ratios give an indication of chest development (Hrdlička 1930, Bass 1971)]?
2. Is there a significant relationship between scapulae with Chancelade borders and more cranially inclined humeral heads and/or wider humeral heads?
3. Is there a significant relationship between broader scapulae, or lower axillary border/scapular height indices and Chancelade-type borders?

All of the data results will be used to determine if a functional explanation is plausible for the differences in axillary border

morphology between Neandertals and modern hominids. If a functional explanation seems acceptable, an attempt will be made to formulate a specific functional explanation for this phenomenon.

### III. PREVIOUS INVESTIGATIONS

#### Theories and Morphological Nomenclature of the Axillary Border

In 1889, Testut first observed that the male Cro-Magnon-type skeleton from Chancelade exhibited an unusual morphology on the axillary border of the scapula. This morphological type, referred to as the Chancelade type, and later called facies axillaris bisulcata by von Eickstedt (1925), is found on 8 of the 25 known Neandertal scapulae (Table I, page 14). Among the Neandertals with this pattern are Shanidar III and six specimens from Krapina. The Skhūl specimens were all classified as Chancelade types by Stewart (1962a) and grouped with Neandertal specimens. It is not clear, however, whether Skhūl hominids are truly Neandertal. Smith (1976b:263) "is reluctant to consider these specimens Neandertal," as the time period of the Skhūl population, 35,000 B.P., seems to make them temporally equivalent with early Upper Paleolithic hominids in Europe. Trinkaus (1977b) places the Skhūl specimens in a category separate from Neandertals and from Upper Paleolithic hominids, and classifies all three Skhūl scapular specimens as having the Chancelade morphology.

Among Upper Paleolithic hominids, the Chancelade type is found in Předmostí III, X, and XI, Chancelade and Combe Capelle (Endo and Kimura 1970, Smith 1976b). Trinkaus classifies all Upper Paleolithic hominids as having the Chancelade morphology (1977b). However, the

Oberkassel male and Předmostí XIV (Endo and Kimura 1970) are said to have the dorsal groove.

Von Eickstedt (1925), in classifying the variations in axillary border morphologies, considered the Chancelade type, as well as a laterally turned ventral type, as in-between or transitional "steps" between the Neandertal type and the modern. He and Vallois (1932) also considered this Chancelade type as "primitive" when compared to the morphology of modern man, maintaining that it is to be found most frequently at "primitive racial levels."

The French paleontologist, Marcellin Boule, first noticed that the morphology of the axillary border in certain Neandertal scapulae differed from the same area in both modern man and the Chancelade hominid. Boule used the scapulae from the La Ferrassie I specimen as substitutes for the missing scapulae of La Chapelle while completing his study of the skeleton from La Chapelle-aux-Saints (Boule 1911/13). Boule noted that both right and left bones of La Ferrassie I exhibit a dorsal axillary sulcus, just the reverse of the normal condition in modern hominids. The dorsal groove is, thus, often referred to as Boule's sulcus (McCown and Keith 1939). The same morphology is also seen in "a very deteriorated piece of one of the scapulae of La Ferrassie II" (Stewart 1962a:782). The La Ferrassie material has been recently re-evaluated by Heim (1974) who further elaborates on these and other scapular characteristics of this material. In addition to the La Ferrassie material, the Neandertal type border is seen on Neandertals from Dusseldorf, Shanidar I, II, and IV, Tabūn I, Spy I and II, Amud I, Vindija, and Krapina scapulae V, IX, XI, and XII (see Table I, page 14). Right and left scapulae are found for Shanidar I;

however, the right bone is fragmented. Stewart (1962a) believes that there are indications of the beginnings of a dorsal groove on this bone. Endo and Kimura (1970) claim that two aged males of the Upper Paleolithic, Oberkassel and Předmostí XIV, have the dorsal groove on the axillary border. However, Trinkaus (1977b) has re-evaluated these specimens from photographs (personal communication) and maintains that they have the Chancelade pattern on the axillary border. Based on the photographs and cross-sections given in the work of the original investigator, Matiegka (1938), the present investigator agrees with Matiegka's conclusion that Předmostí XIV has a dorsal groove on the axillary border.

Schwalbe (1914) synthesized the data on Testut's Chancelade type and Boule's Neandertal type and introduced the term "sulcus axillaris" for the groove on the axillary border of the scapula. Believing this phenomenon to be merely the movement of one sulcus which changed position over time, Schwalbe did not differentiate between varying orientations of the sulcus. This situation was somewhat remedied by Gorjanovič-Kramberger (1914) who restudied and reclassified the Krapina scapulae in the light of the aforementioned discoveries and began to use the terms sulcus dorso-axillaris for the Neandertal pattern, and sulcus ventro-axillaris for the modern pattern.

Von Eickstedt (1925) elaborated on Gorjanovič-Kramberger's differentiations by noting muscular insertions on the border and imposing the use of the names of muscles in describing the border. Thus he named the dorsal (Neandertal) groove sulcus axillaris teretis observing the dorsal insertion of the teres minor muscle, and the ventral groove sulcus axillaris subscapularis, noting that the

subscapularis muscle has partial origin in the ventral sulcus. The Chancelade type, having a double groove, was called facies axillaris bisulcata by von Eickstedt.

Aside from clarification of terminology, von Eickstedt's purpose was to disagree with Schwalbe's contention that the sulcus had moved in the course of time. Von Eickstedt believed that there were two morphologically different structures, and not merely a "wandering around" of the sulcus from the ventral to the dorsal side of the axillary border. Von Eickstedt also believed that Schwalbe's suggestion that a new muscle had appeared dorsally was incorrect. Another area of disagreement between von Eickstedt and Schwalbe concerned Schwalbe's placement of the infraglenoid tubercle at the cranial beginning of the "labium dorsale" in the Neandertals. The "labium dorsale" is the bone strut or "lip" which dorsally confines or defines the dorsal groove. Von Eickstedt believed that Schwalbe had misinterpreted the placement of the infraglenoid tubercle due to the amount of damage on the Neandertal specimens available to Schwalbe; and that the tubercle is actually at the start of labium laterale as seen in the La Ferrassie specimens used by Boule. Von Eickstedt also stated that the tubercle is at the start of labium laterale in a specimen with a "massive dorsal visible sulcus a teretis on a right scapula photographed by Gorjanović-Kramberger from the Krapina remains . . ." (von Eickstedt 1925:220, translation mine). He concluded, with regard to the morphological differences on the axillary border, that although "function modifies the shape of the scapula, it is not to be assumed that function is always exclusively responsible for the shape of the

border as there are innate racial differences" (von Eickstedt 1925: 221, translation mine).

Von Eickstedt surveyed scapulae of Homo sapiens from various parts of the world. Of 409 scapulae investigated, 26 or 6.4% exhibited the dorsal sulcus, 65 (15.6%) had a suggestion of a dorsal sulcus, 95 (31.4%) were of the Chancelade type, and 135 or 44% had the "European" or "normal" modern type (ventral sulcus). One must view these findings cautiously, however, since von Eickstedt did not make it completely clear which variations he accepted as dorsal.

Problems of exact classification also arose when Gorjanović-Kramberger once again restudied and reclassified the Krapina scapular material in 1926. Three of the 17 scapulae were said to be the Neandertal type: IX, XI, and XII; and five were said to be Chancelade type: VII, X, XIII, XIV, and XIX. Seven were considered as unclassifiable or uncertain. Of these seven, five are juveniles, which are always difficult or impossible to classify, especially if very young. Smith (1976b) restudied these scapulae and reclassified scapula V (125) as a Neandertal type, and scapula VII (127) as the Chancelade type. It has been determined that one Krapina scapula (VI) bears the ventral, or modern, morphology on the axillary border (Trinkaus 1977b, Smith 1978b).

The high percentage of Chancelade types at Krapina appears rather unusual since this percentage is somewhat higher than that which is found in the total Neandertal sample. Stewart (1962a) has questioned the dating of this skeletal material to the Riss-Würm Interglacial period. In all other sites, the Chancelade type is found

in greater frequencies in material of the Upper Paleolithic. But Smith (1976b:265) explains:

the hominid remains come from all levels of Krapina and span a time period from the end of the Riss-Würm to the Würm I/II interstadial. The stratigraphic origin of the scapulae are not yet known, and it is possible that specimens exhibiting the Chancelade type come from higher in the Krapina sequence. Even if all the scapulae came from a Riss-Würm level, it does not necessarily mean this early date is in error. For example, the largest sample of scapulae from a single Neandertal site except Krapina is two. Thus, the actual frequency of the Chancelade type in Neandertal populations may be higher than presently believed.

Recently, Trinkaus (1977b) speculated on the causes of the differences on the axillary border between Neandertal and modern hominids. Trinkaus based his functional interpretation of this problem on the theory that the Neandertal cultural adaptive level would have produced greater biomechanical stress in the shoulder region. It can be seen from the very large deltoid tuberosities on Neandertal humeri that the deltoid muscle was very powerfully employed. Thus, muscles which work in conjunction with the deltoid muscle during abduction to maintain the head of the humerus in the glenoid fossa would have had to exert greater force. The teres minor is one of these resistive muscles, as well as being one of the muscles which laterally rotates the humerus.

#### Other Features of the Neandertal Scapula

Other areas of the scapula have been studied by all of these scholars and certain features which appear repeatedly in Neandertals should be noted. One of these features is the scapular notch on the superior border. Boule (1911/13) noted that the Neandertal scapulae which he had observed had large scapular notches, and he considered this to be a Neandertal characteristic. Vallois (1946) agreed with

this contention. The specimens at Krapina were found to have large notches, as does Shanidar I (Stewart 1962a, Smith 1976b). McCown and Keith (1939) described Skhūl V and Tabūn I as having small notches; however, Stewart claims that breakage in both these cases misled those authors and that "it seems unwise, therefore, to conclude that the Mount Carmel scapulae have the lateral part of the superior border shaped differently from that of other Neanderthals" (Stewart 1962a:794).

In 1939 McCown and Keith studied the shoulder girdle of the specimens from Mount Carmel. The axillary borders of Tabūn I, Skhūl IV, V, and IX were compared with the right scapula found near Dusseldorf for its Neandertal-like characteristics. Among other interesting points, they noted that the proportion of the length of the axillary border of these specimens to the maximum length of the humerus (scapulohumeral ratio) was slightly different than in modern groups. The significance of the proportionally shorter border of the Skhūl specimens is not known. McCown and Keith gave much attention to the study of the length and strength of the axillary border because they regarded it as "the main lever of the scapular system, providing the means by which the most powerful part of the serratus magnus may rotate the shoulder and raise the forelimb on the body" (1939:132). They also mention that the Mount Carmel scapulae are relatively shorter from the glenoid cavity to the vertebral border than in modern hominids and that "It is apparently the rule for the scapula to be relatively short (or narrow) in Paleoanthropic races" (McCown and Keith 1939:131). In other words, modern races have generally higher indices than this group.

McCown and Keith also discussed the dorsal inclination of the glenoid cavity of Neandertal scapulae. After investigating the possibility of dorsal deflection in their material, they concluded that the great deflection in the original Neandertal specimen was an extreme individual variation. Stewart's (1964) re-evaluation of this matter will be discussed later.

McCown and Keith (1939) noted that the axillo-glenoid angle in the Dusseldorf scapula ( $145^\circ$ ) and Krapina scapulae ( $134^\circ$ - $146^\circ$ ) is greater than in modern humans, but concluded that the Palestinian specimens are not Neandertal-like in this respect. Tabūn I has an angle of  $132^\circ$  and that of Skhūl is  $127^\circ$ . The modern range is  $120^\circ$ - $135^\circ$ , a greater cranial deviation than the angle for Neandertals. With regard to the morphology of the axillary border, McCown and Keith reported that Skhūl V and IX have the Chancelade type, Tabūn I has a highly developed dorsal sulcus, and the preserved segment of the Skhūl IV scapula appeared to have an incipient stage of a dorsal groove. Stewart (1962a) and Trinkaus (1977b), however, consider all three Skhūl specimens as Chancelade types.

McCown and Keith believed the Mount Carmel scapular series bridged "the gap which exists between the state found in the western European Neanderthalian and that which prevails among modern races" (1939:136). They considered the presence of the dorsal sulcus somewhat of a racial characteristic. Another interesting viewpoint expressed was: "The modern condition represents the old or anthropoid condition, while the marginal fossa of Neanderthal man is an evolved and later acquisition" (McCown and Keith 1939:136). In sum, the Mount Carmel scapular specimens were regarded by McCown and Keith as

belonging to the same group as the Neandertals of Europe; although they were moved to separate the Tabūn type from the Skhūl form because of the morphology of the coracoid process.

The coracoid process is a differentiating feature at Mount Carmel in that Skhūl V shows "the markings for the coraco-clavicular ligaments, the trapezoid and the coracoid . . . as in the modern coracoid, quite different from those seen in the same part of the Tabūn scapula" (McCown and Keith 1939:138). This process is also peculiar to Tabūn I, as the post-glenoid root begins as a thickening on the dorsal lip of the glenoid. McCown and Keith found this to be similar to the fractured coracoid remains of the original Neandertal specimen. Stewart (1962a) called attention to the lack of a well-developed "heel" at the proximal end of the horizontal part of the coracoid of Shanidar I, which is also a feature of Tabūn I. This "heel" is seen in Skhūl V and generally in modern humans. The portions of eight coracoids found at Krapina, however, seem to be basically modern (Smith 1976b). At Krapina, it must be recalled, the stratigraphic levels and hence the dates of the various scapulae are still uncertain.

Commencing in 1928 and continuing in a series of publications until 1946, Vallois made a very thorough survey of the general features of the human scapula. Included in this survey is a considerable amount of information and study on the axillary border, notably detailed descriptions of the axillary borders of three Neandertal scapulae and two Upper Paleolithic specimens (Vallois 1932). Vallois reports that, contrary to von Eickstedt's findings, no Neandertal types are found in any modern hominids and the Chancelade type is

observed only rarely. Thus, according to Vallois, the true Neandertal type is unique to Neandertals. He maintains that robust scapulae, usually those of men, have thicker borders and a well-marked ventral gutter oriented more laterally than in less robust scapulae. The teres minor surface is also larger on the scapulae of individuals with heavy muscular markings. Vallois further suggests that "exotic" races of modern humans are very different from Europeans in that one more frequently finds robust morphologies in these groups. On this point, Vallois and von Eickstedt are in agreement. Von Eickstedt (1925) found most of the robust and/or Chancelade types in Bushmen and other "primitive" groups; and Vallois found the greatest number of Chancelade types in Melanesians and Australian aborigines.

Vallois sought to interpret the variations on the axillary border by considering muscle attachments. He noted that the insertion of subscapularis on the ventral surface is often by the most external fascies of subscapularis. As stated elsewhere, the teres minor muscle inserts on the dorsal surface of the border. As teres minor and the external fascies of subscapularis are the stabilizers and rotators of the arms--the former rotating laterally and the latter medially--Vallois believed the Chancelade type was a result of very powerful movements of elevation of the arms. Vallois also believed it was possible that the subscapularis accessory differentiates completely from the subscapularis muscle proper; however, according to him, this point of myology was not documented. Vallois considered the Neandertal type border more difficult to explain (1932). "The obviously greater development of teres minor with the resulting weak development of subscapularis may be due to the movements of elevation

being habitually accompanied by rotation of the arms to the outside instead of rotation to the inside as in modern man" (Vallois 1932:49, translation mine). Consequently, the muscle which lowers and rotates externally predominates at the cost of the muscle which lowers and rotates internally. Coon (1962) also believes that the muscles that roll the humerus outward from the trunk were powerfully used.

Vallois also studied the axillo-glenoid angle of the scapula, noting that anthropoids' glenoid cavities deviate cranially ( $107^{\circ}$ - $109^{\circ}$ ) and man's, laterally ( $120^{\circ}$ - $135^{\circ}$ ). There are, however, differences in this feature among the races of modern men, and Vallois considered the more cranially inclined cavity of the "Negrilles" as "primitive." Although the Neandertal range of  $139^{\circ}$ - $146^{\circ}$  is dissimilar from the normal modern range, Vallois claimed that Neandertals cannot be totally distinguished from modern people either by this orientation or by a particularly dorsal orientation of the fossa. The tendency for slightly more cranial deviation of the fossa may be a point of a continuum in the gradual evolutionary transformation of man from the brachiation state of his ape-like ancestors to the bipedalism of man. The Australopithecine glenoid cavity is cranially deviated (Sterkfontein 7 - Broom et al. 1950). The Australopithecine shoulder girdle anatomy supports the theory of mosaic evolution in that these earliest hominids may have frequented an arboreal environment while perfecting bipedalism on the ground (Ciochon and Corruccini 1976).

Stewart (1962a) further discussed the relative narrowness of the Neandertal glenoid fossa, a feature cited by Vallois as a tendency among these hominids. Stewart agreed with Vallois and found a narrow glenoid fossa to be a characteristic of the scapulae from the

Shanidar site. Stewart pointed out, however, that although the height/breadth indices of the fossae of Neandertal's are lower than those of modern humans, they are not entirely beyond the upper portion of the modern range. They do not, therefore, completely differentiate Neandertals from modern hominids. The wider axillo-glenoid angle and a broad scapular notch are two other Neandertal features with differing tendencies but they, too, are within the modern hominid range. Stewart (1962a) concluded that the form of the axillary border is the only distinguishing feature between the scapulae of modern hominids and Neandertals. Additionally, he classified both the left and right scapula of Shanidar I as Neandertal types, but Shanidar III as a variant of the Chancelade type.

In 1964 Stewart investigated the contention that the original Neandertal scapula has an unusual backward tilt of the glenoid cavity. Klaatsch (1901) had originally reported this and Schwalbe (1906) had agreed. McCown and Keith (1939), however, believed this unusual inclination to be an extreme variation peculiar to this individual. Vallois (1932) had suggested that the marked inclination of the Dusseldorf scapula was nothing more than an illusion. Stewart (1964) concluded that the degree of dorsal inclination is slightly greater in the Dusseldorf specimen's glenoid cavity than in modern humans but that pathological arthritic changes on this specimen probably distorted the measurement. Stewart believes that this individual's left scapula, had it been found, would have been within the modern range in dorsal inclination of the cavity. He reasoned that the dorsal inclination of the glenoid cavity is more pronounced on the right side than on the left side because the Neandertal specimen--having

suffered an injury to his left elbow--probably used his right arm excessively thus provoking greater arthritic buildup. Stewart (1962a) also points out the unusually horizontal disposition of the scapular spine of the Shanidar hominids.

In the postcranial studies of the Amud man, Endo and Kimura (1970) also investigated the dorsal inclination of the glenoid cavity. They emphasized that the marked inclination does exist and is not merely an extreme variation of the individual from Dusseldorf. They also noted that Amud I compares with Dusseldorf in the narrowness of the glenoid cavity and has a distinct sulcus dorso-axillaris.

Helm (1974) has remarked on the great enlargement of the glenoid cavity of the La Ferrassie subjects. He also pointed out the unusually high glenoid index, especially on the right scapula. While the index, 68.1, is larger than that of some of the other Neandertals', it remains within the basic Neandertal range and within the tendency for narrow glenoid cavities. Stewart (1962a) and Smith (1976b) agree that Neandertal glenoid fossae indices fall within the upper ranges for modern man and thus do not totally distinguish Neandertal from modern hominids. In general, the La Ferrassie subjects were very robust and had strong musculature, especially in thoracic and scapular muscles. According to Heim (1974) these specimens also exhibited deep infraspinous and subscapular fossae.

#### General Scapular Studies

Anthropological studies on the scapula usually are concerned with studying the proportions of the bone to establish racial and sexual differences. Few studies have been concerned with the

morphology of the axillary border. A short description of typical anthropological studies is necessary.

In their study of the scapula, Bainbridge and Genoves (1956) discuss, among other things, the axillary border with regard to differences between the sexes. They disagree with Vallois (1932) concerning the median axillary crest. Whereas Vallois said this crest is more distinct in females than males, Bainbridge and Genoves find it is sometimes poorly developed in females and well marked in males. Occasionally a pronounced dorso-axillary crest replaces it. They found a 65-year-old male who looked much like the Neandertal type due to a strongly developed dorso-axillary crest (which transgressed the infraspinous fossa) and a very light ventro-axillary crest which disappeared below the middle one-third of the border. They also found that a laterally directed ventral gutter is more commonly found in male bones, especially on the bones of robust individuals. They considered this characteristic as one of the better methods of determining sex from the scapula, when used by an experienced observer. Bainbridge and Genoves devised a scoring system for sexing scapulae which utilized measurements of length, breadth, axillary border width, glenoid cavity length and width, and length of the axillary border.

In a study of the shoulder girdle of the Australian aborigine, van Dongen (1963) reported that the dorsally inclining lower part of the axillary border, which increases the area of origin for the subscapularis muscle, is more pronounced in male bones. Contrary to Bainbridge and Genoves, who suggested this characteristic as a guide to sex, van Dongen stated that it is merely an expression of muscular development. Van Dongen quantified this dorsal inclination as to sex:

18% of males and 50% of females had a small extent of dorsal inclination area; 33% of males and 30% of females were moderate; 49% of males and 20% of females had extensive areas of dorsal inclination.

Van Dongen's study involved 216 humeri, 134 scapulae, and 103 clavicae of Australian aborigines. In general, he found that the shoulder girdle and humerus of aborigines fall within the normal range of human variation. However, the scapulae in Australians of both sexes tend to be shorter and narrower than in most other groups. Van Dongen stated that functional responses of the bone are responsible for the differences.

Graves (1921) was interested in the contour of the vertebral border and quantified three types (concave, straight, and convex) in his study of this area in various populations. He attempted to correlate the various types of vertebral borders with other features of the scapula. He found that the "straight" and "concave" contoured scapulae had much in common and classified them as "scaphoid." A large percentage of early and contemporary populations have the scaphoid type although in ancient Egyptians the convex is the predominating type. He concluded that all three types are found in all ancient and modern groups and were probably primeval with man.

In a further study, Graves (1939) concluded that these various forms are determined by intrinsic genetic factors and that the scaphoid type is indicative of a very weak constitution of the individual. However, Frey (1923), upon studying human specimens, concluded that specialized functions are responsible for the variations in the shape of the scapula in general, and the vertebral border in particular. Schultz (1930), after noting much muscular variation

in gorilla and man, concluded that variations in the mode of muscle insertion can influence the contour of the scapula. Wolffson (1950) performed experimental studies on rats' vertebral border muscles and concluded that function, not heredity, greatly affects the shape of the vertebral border.

Hrdlička (1942a,b,c) contributed a large, thorough series of studies of the scapula to the literature. In discussing the various shapes of the body of the scapula, he remarked that the types reflect, to some degree, the varying development of the vertebral border which is "doubtless largely of functional causation; but to some extent they also occur genetically in bones of various dimensions, and to that extent fall within the scope of human heredity and typogeny" (1942a: 76). Hrdlička disagreed with Graves' attempt to connect the concave type with pathology or constitution, saying that this would only apply to conditions that produced a weakening of the muscles attached to the bone during childhood and continued throughout the growing period. Hrdlička believed that a basic tendency to a particular form is inherited with "the result subject to functional modification" (1942a: 77), as in all other bones of the skeleton. Thus the forms are partly determined phylogenetically, and partly acquired ontogenetically.

Forms of the various borders, side differences, racial and sex differences were studied in Whites, North American Indians, Eskimos and American Negroes in these 1942 studies by Hrdlička. Hrdlička's works largely confirmed the data of Vallois with regard to the reality of the existence of racial characteristics of the scapula. Hrdlička also determined that while male scapulae are absolutely larger, female scapulae are relatively broader and shorter (1942c). This is

similar to the condition in human juveniles. This phenomenon may be related to the amount of muscular load placed on the bone; experimentally atrophied rat scapulae are shorter and wider than normal scapulae (Riesenfeld 1966). Hrdlička also attributed this difference to ontogenetic factors (1942c). Schultz (1930) found differences between the races in scapular index. In his study, whites had the broadest scapulae of all racial groups.

Gray (1941) determined the frequencies of certain features not discussed in normal accounts on the scapula or those which deviate from descriptions in most anatomy texts. Some of these are: a sulcus for the circumflex scapular artery, anomalous scapular foramina, muscular cristae, shape of glenoid fossae, and shape of the acromial process. He concluded that genetic factors play the major role in producing certain variations, but that their manifestation may occasionally be influenced by special functional factors.

Sexual differences and asymmetry of morphological features of the scapula was investigated on Portuguese scapula collected by the Instituto de Coimbra (Xavier De Morais 1968). In general, the Portuguese scapulae are similar to other groups of European scapulae which had been studied. Perforations of the scapula and the presence of infracoracoidal canals were the only anomalous characteristics of these scapulae. The axillary border of this population exhibited the "European type" (ventral groove) in 75.6% of the cases. The investigator found no sex differences with regard to axillary border morphology; however, she did find a predominance on the right side of borders with the bisulcate morphology.

### Functional Studies of the Shoulder Girdle

Roentgenographic studies of movement in living subjects offer helpful insights into muscular relationships and function during various types of movements. Inman, Saunders and Abbott (1944) examined the functional mechanism of the shoulder from several aspects. In comparing various forms with regard to the progression toward freeing of the forelimb, they explored various characteristic skeletal changes. The study focused on radiological analysis during elevation of the arm in living subjects. Their purpose was to note relative use of various muscles and relative movement of the various bones of the shoulder area. They noted that "striking alterations in the muscles, in respect to both their size and points of attachment, . . . suggest that the functional demands of the extremity, expressing themselves through the action of the muscles, have caused the skeletal changes" (Inman et al. 1944:4).

While Inman et al. had conducted their studies of abduction in the coronal and frontal planes, Freedman and Munro (1966) studied the complex varieties of movements during abduction of the arm in the scapular plane. This study was also conducted roentgenographically using living subjects. Relative amounts of scapular and glenohumeral movements were calculated in each subject during this procedure.

Oxnard has authored or coauthored a number of studies on primate scapulae or shoulder girdles, usually with regard to locomotor function. In an effort to extract a picture of functional adaptation of the shoulder region he chooses characters or dimensions for his morphometric studies which show both locomotor and taxonomic correlation. While these studies rarely offer information directly relevant

to the problem of this thesis, they do offer insight into methods of study and some effects of function on the morphology of the bone itself. Once it is realized that certain features of the shoulder girdle are mainly functionally adaptive, one can use these morphometric features and consider functional mechanisms with regard to related muscular masses (Oxnard 1967). For example, one study compared the shoulder girdles of brachiators and quadrupeds. Results indicated that in brachiators the glenoid cavity is directed more cranially and the clavicle is longer, with its lateral end twisted more cranially than in the quadruped. It is thought that these differences may be associated with the habitual motions of brachiators and quadrupeds (Ashton and Oxnard 1964, Ciochon and Corruccini 1976). Man's glenoid cavity is more similar in orientation to quadrupeds than to brachiators because the arms hang downward from his shoulder (Campbell 1966). This is believed to be one of the ways that bipedalism has influenced the shape of the scapula. Other features of muscular insertion can show that the mechanisms for rotating the scapula as the arm is raised is more effective in brachiators than in quadrupeds.

## CHAPTER II

### MATERIALS AND METHODS

#### I. MATERIALS

The sample analyzed for this study is composed of several series of skeletal populations. The various populations differ temporally, racially and in technological level.

The largest group studied here, Averbuch, is an archeologically collected skeletal population of American Indians from Middle Tennessee. The Averbuch site is located in the Bordeaux section of North Davidson county and is representative of the Mississippian period in the Nashville basin, dated to 1400 to 1550 A.D. (Reed 1978). The sample consisted of 204 burials, most of which had been in "stone boxes," resulting in relatively good preservation.

The second study population consisted of 175 skeletons from the Terry Collection in the Smithsonian Institution of the National Museum of Natural History. The Terry Collection is an American dissecting room collection extending from the 1920's to the present. The samples for this study consisted of 81 black males and females and 94 white males and females. The specimens used ranged in age from 20 years to 65 years. The samples were selected to give a relatively even age and sex distribution; however, the white female sample is somewhat deficient as the Terry Collection includes very few with recorded ages of less than 30 years. Conversely, there are excessive numbers, especially among the white males, of very aged individuals.

In order to eliminate distortions that may occur due to extensive aging effects, and to keep a balance with regard to age, individuals over 65 years were generally excluded.

Data were also collected from Eskimo skeletal material housed in the Division of Physical Anthropology, the Smithsonian Institution. One population of Eskimos had inhabited St. Lawrence Island in the 18th and 19th Centuries and was collected by Riley D. Moore. Eskimo skeletal material collected from various sites on the Seward Peninsula was also used here. The Peninsula is on the mainland across from St. Lawrence Island. Even though St. Lawrence Island appears far removed from the mainland, the populations are believed to be related peoples because the move from the mainland was made in relatively recent times (Oswalt 1967). Additionally, both populations were Yupik speakers, had similar technological levels, and were equally adept at boatmanship and open water hunting (Dumond 1977).

Skeletal remains from the Middle and Late Archaic Cultural period in the Eastern U.S. comprised a fourth series for this study. Much of the material is from the Eva site, with additional material from the Cherry and Ledbetter Landing sites. All of these sites are located in the western Tennessee River Valley, Benton County, Tennessee. These sites are geographically close to each other and culturally related. The sites range in time from approximately 5000 B.C. to 2000 B.C. according to relative and absolute dates (Magennis 1977).

All skeletal material used in the study was adult material. Age and sex for each individual in the Terry Collection are documented and recorded. Information on the age and sex of the Eskimo

material and part of the Archaic material was available; however, this investigator studied each specimen to confirm the previous determinations. The Averbuch material is currently under study by other investigators, thus previous age and sex determinations were not available for much of the material. Pelvic morphology was the primary criterion used to determine age and sex for this study (Bass 1971). Other aspects of skeletal morphology were relied upon when pelvic morphology was not observable.

## II. METHODS

The study material was divided into groups according to age and sex. Females were separated from males for the statistical studies and each sex grouping contained three age categories: 18-30 years of age; 30-40 years of age; and 40 years of age or older. This procedure served to facilitate comparisons and observations concerning the premise that morphology is a function of age and muscular exertion.

The morphology of the axillary border of the scapula, the major focus of interest here, was carefully noted for each scapula used in this study. The morphology of the axillary border was classified into two major categories as follows:

1. Type 1: an axillary border with a ventral sulcus. This is considered the "modern" or "normal" type for anatomically modern Homo sapiens (Figures 1B and 3A, pages 9 and 11, respectively). This type also includes those axillary borders with a ventral groove which is oriented more laterally than ventrally. (This type was considered an intermediate type by von Eickstedt 1925.)

2. Type 2: the Chancelade or bisulcate type. A crest divides the laterally oriented axillary border into two grooves. The ventral groove is usually slightly larger than the dorsal (see Figures 1A and 3C, pages 9 and 11, respectively). This type also includes bisulcate borders which are slightly more ventrally oriented and those with a more dorsally oriented dorsal groove.

The maximum width of each axillary border was measured. This measurement was helpful in determining handedness, as the right border is usually wider than the left in right-handed persons (Hrdlička 1942a). The length of the axillary border was measured from the most caudal point on the rim of the glenoid fossa to the lowest point on the inferior angle (see Figure 4). Sliding calipers were used for both measurements. The length measurement was needed to compute the ratio of the axillary border to the maximum height of the scapula. This ratio is slightly different in modern humans from that of Neandertals (McCown and Keith 1939). The ratio was computed as follows:

$$\frac{\text{Axillary border length} \times 100}{\text{Height of scapula}}$$

Scapular height was taken: "the maximum straight line distance from the superior to the inferior border" (Bass 1971:94); and breadth was measured from the central point on the end of the spinal axis on the vertebral border to the central point on the dorsal rim of the glenoid fossa (see Figure 4). The scapular index is determined as follows:

$$\frac{\text{Maximum breadth} \times 100}{\text{Maximum length (height)}}$$

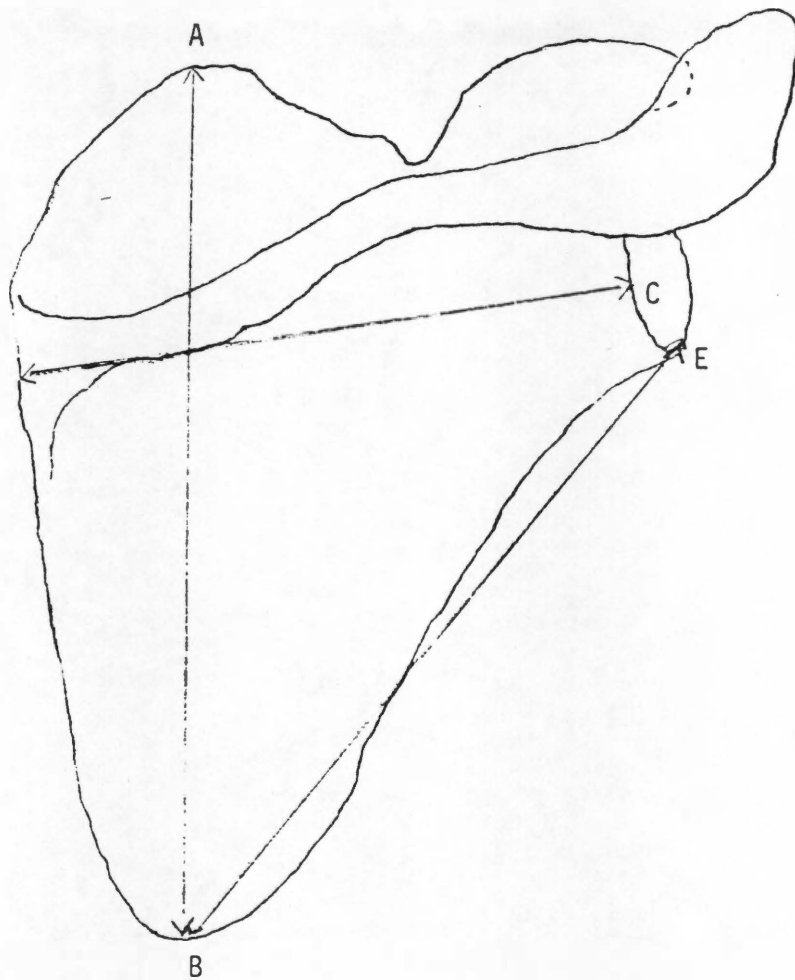


Figure 4. The scapula of man, dorsal view. Measurements of scapular height are taken from A to B, scapular breadth is taken from C to D. Axillary border length is from B to E. From Bass, 1971.

McCown and Keith (1939) found that scapular indices of Neandertals differ slightly from those of modern hominids. The proportion of scapular breadth to humeral length also differs in Neandertals (Trinkaus, personal communication) and the index was computed:

$$\frac{\text{Scapular breadth} \times 100}{\text{Maximum humeral length}}$$

Among the purposes of this study is to determine whether there is any consistent relationship between the morphology of the axillary border of the scapula and the shape of the thorax. The great curvature of Neandertal clavicae is well documented in the literature and conforms well with the general picture of the barrel-shaped chest of Neandertals (Hrdlička 1930, McCown and Keith 1939, Smith 1976b). Curvature indices for Neandertal clavicae range from 11 to 15 while the range is approximately 6 to 11 for modern humans (McCown and Keith 1939).

Clavicular measurements were taken in order to find the index of clavicular curvature for the samples studied here (see Figure 5). The maximum length of each clavicle was taken according to the method described in Martin (1928). An osteometric board was employed for this measurement. For the measurement of the medial curve, an attempt was made to follow Martin's method of measuring the "height of diaphysis curvature" (1928:527). "Laying the bone across the measuring board so that the sternal curvature and the back arch of the acromial end push against the vertical walls, measure the most projecting point of the anterior arch" (translation mine). The height of the

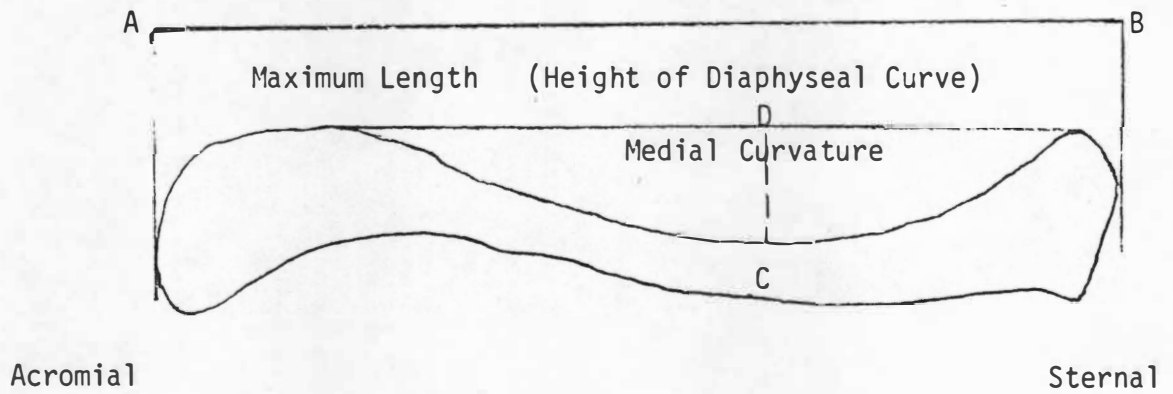


Figure 5. The clavicle of man. Measurements of maximum length are taken from A to B. Measurements of medial curvature are from C to D. From McCown and Keith 1939.

diaphyseal curvature was multiplied by 100 and divided by the maximum length, thus yielding the index of curvature.

$$\frac{\text{Height of Diaphyseal curvature} \times 100}{\text{Maximum Length}} = \text{Index of Curvature}$$

Two measurements were taken on the humerus that are relevant to the relationships found in the shoulder area. As Neandertal humeral heads often measured greater transversely than vertically (McCown and Keith 1939), these measurements were taken and humeral head indices were calculated. The transverse measurement was determined by placing the sliding calipers horizontally on the humeral head and finding the maximum distance from rim to rim of this hemisphere. The caliper points were placed at the most proximal tip and the most distal tip of the rim in order to find the vertical measurement (Martin 1928).

Since it was reported in several studies of Neandertals (particularly by McCown and Keith 1939) that Neandertal humeral heads are more cranially directed than those of modern humans, the angle of the humeral head to the diaphyseal axis was measured. The humerus was placed on an osteometric board with the anterior side facing downward (Martin 1928). In this position, the humeral head was seen in profile. Two threads were attached to the head of the board. One thread was drawn parallel to the axis of the head in profile, following a point on the most proximally seen portion of the rim to a point on the most distally seen portion of the rim. Another thread was drawn down the axis of the shaft. At the point where these two lines intersected, a protractor measured the angle between the two lines.

Measurement of the maximum length of the humerus was taken using an osteometric board. The measurement was useful for the

following purposes: 1) To determine whether the individual was right-handed, and, ultimately, whether each population proved to be predominately right-handed. 2) To compute the ratio between the maximum scapular breadth and the maximum length of the humerus. The preceding two ratios were suggested by the findings of McCown and Keith and of Trinkaus and have been discussed above. 3) To compute the claviculo-humeral index. This index was computed and tested in order to discern whether there is any relationship between a high or low index and the morphology on the scapular border. According to Hrdlička (1930), the ratio between the maximum length of the clavicle and humerus yields an indication of the development of the chest. According to McCown and Keith (1939) the claviculo-humeral index in Neandertals is relatively high compared to modern hominids.

### Statistical Analysis

Multivariate Analysis of Variance. Computation of indices and statistics used in analyzing the various sets of data was carried out on the IBM 370/system computer at The University of Tennessee, Knoxville. The Terry Collection data were analyzed by Multivariate Analysis of Variance (MANOVA) using the General Linear Models procedure (GLM) in the Statistical Analysis System (SAS 76--Barr et al. 1976). This method was utilized in order to discern whether there were statistically significant differences between the two morphologies for the various indices. In the GLM procedure, the dependent variable may be quantitative, as in regression analysis, but unlike regression analysis, the independent variables may be qualitative. The use of the MANOVA program was possible only for the Terry Collection as this

is the only set with complete data. The MANOVA model allows multiple testing of variables for morphological effects due to the combined variables.

In this procedure, an F-value or ratio is formed to test the significance of the analysis. Data were taken to be significant if the probability was less than .10. There is an F-value to test the overall significance of the model, the combined indices; and a univariate F-value for each of the indices in the set.

Effects of morphology were tested with regard to four combined variables or three combined variables (in two separate runs) and classified or differentiated by sex and race. The sides of the body were treated separately. The four variables considered jointly in the first run were: scapular index, scapular-humeral index, index of clavicular curvature, and axillary border-scapular height index. The second run considered the morphological effects of humeral head index, humeral head angle, and clavicular-humeral index.

Principal components analysis--Terry Collection. The data on blacks and whites in the Terry Collection were subjected to the principal components analysis procedure (PAI option) of the Statistical Package for the Social Sciences (SPSS-6--Nie et al. 1975). Input to SPSS FACTOR was a within groups correlation matrix, calculated by WITHIN, a modification of a portion of the discriminant analysis program found in Davies (1971). Principal component analysis is a data reduction technique. It aids in reducing a larger number of variables to a smaller number of valid clusters or factors which can help to determine the degree to which one or several variables are

relevant to a unifying, underlying phenomenon or problem. The procedure produces a set of orthogonal (uncorrelated) components while retaining virtually all the original information, which is often overlapping.

The components are rotated using the VARIMAX procedure (Kaiser 1958), which facilitates morphological interpretations. Each component will have certain variables which "load" on the component. Those variables contributing the most to the component will have "loadings" approaching 1.0, and those contributing little information approach zero. Component scores were obtained by means of the Fortran program Z-SCORE, which standardizes the data matrix and multiplies it times the factor score coefficient matrix. Component scores obtained in this manner have grand means of zero and unit variances.

#### Condescriptive and discriminant analysis--Terry Collection.

The CONDESCRIPTIVE program of SPSS 6 (Nie et al. 1975) used the component scores as input data to calculate group means of the principal components. Differences between the racial and sexual groups (black, white; male, female) could then be tested for significant differences. The Normal Deviate was obtained by calculating the standard error of difference between means and dividing it into the difference (Fisher 1950).

$$\text{Normal Deviate} = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

Further analysis of the principal component scores was performed by the DISCRIMINANT program of SPSS6 (Nie et al. 1975) to seek

statistical distinctions between the two border morphologies for the six components. The analysis aspect of this program provides statistical tests for measuring the success with which the discriminating variables actually discriminate. Thus the variables which contribute most to differentiation between the two morphological types on the border can be identified.

Univariate General Linear Models procedure--all groups. The remaining groups under study had incomplete data and were thus given different treatment. The General Linear Models procedure (hereinafter abbreviated GLM) of SAS 76 (Barr et al. 1976) was employed. GLM is a regression procedure which handles classification variables (discrete) as well as continuous variables. This program was chosen for its ability to do analysis of variance (ANOVA) for unbalanced data. The model which was used tested the relationship between each index or angle to sex, age, morphology, and race. In other words, the dependent variable in each case was an index (or angle) and the independent variables in each case were sex, age, morphology and race.

Crosstabs--all groups. Finally, all groups studied were subjected to the SPSS6 program CROSSTABS to find relationships between the morphological types on the axillary border with race, sex and age. The program CROSSTABS "computes and displays two-way to n-way cross-tabulation tables for any discrete variables, either numeric or alphanumeric" (Nie et al. 1975:218).

## CHAPTER III

### RESULTS

#### I. STATISTICAL ANALYSES

##### Multivariate Analysis of Variance--Terry Collection

The Terry Collection sample was subjected to a multivariate analysis of variance (MANOVA) from the General Linear Models (GLM) procedure of SAS76 (Barr et al. 1976). The null hypothesis tested was that the two morphological types show no differences in the indices used. Univariate F-values were interpreted if the null hypothesis was rejected by the overall test (F-value) for combined indices. For the treatment by race and sex a sampling of 25 individuals with the ventral morphology on both scapulae, and 25 with the bisulcate (Chancelade) pattern on the axillary border were selected from each racial group (morphologies may differ on each side of the body in an individual). Further statistical handling included the total sample of 175 individuals. The sides of the body were treated separately.

The results of the Manova GLM analysis can be seen in Tables II and III. The four variables considered jointly in the first analysis were: scapular index, scapular-humeral index, clavicular curvature index, and axillary border-scapular height index. Those race and sex combinations for which the morphologies are statistically different ( $p < .10$ ) using Wilks' criterion (and individual ratios) are reported.

Overall significant morphological effects were seen in white males on the left side. Contributing to this difference in

TABLE II

MANOVA TREATMENT FOR MORPHOLOGICAL VARIATION FOR FOUR VARIABLES--TERRY COLLECTION<sup>a</sup>

	Left				Right				Overall	
	Blacks		Whites		Blacks		Whites		L	R
	Male	Female	Male	Female	Male	Female	Male	Female		
Scapular Index	p=.05 F(1,6)= 6.09	p=.03 F(1,9)= 7.09	p=.08 F(1,5)= 4.78			p=.02 F(1,9)= 8.15				
Scapular Breadth/ Humeral Length			No Statistical Significance for this Index							
Clavicular Curvature Index			p=.04 F(1,9)= 7.5				p=.007 F(1,9)= 12.2		White males p=.09 F(4,2)= 10.24 (Clavicular Curve & Axillary Border/ Scapular Height)	
Axillary Border Length/ Scapular Length	p=.01 F(1,5)= .01	p=.099 F(1,5)= 4.06				p=.04 F(1,4)= 8.70				

<sup>a</sup>Four variables were treated jointly for evidence of morphological effect: scapular index, scapular breadth/humeral length index, clavicular curvature index, axillary border length/scapular height index. The MANOVA GLM procedure (SAS) was used for the statistical analysis. In "Overall" column, parentheses enclose names of variables which were major contributors to overall effect. Only those indices with  $p < .10$  are in the table.

TABLE III

MANOVA TREATMENT FOR MORPHOLOGICAL VARIATION FOR THREE VARIABLES--TERRY COLLECTION<sup>a</sup>

	Left				Right				Overall	
	Blacks		Whites		Blacks		Whites		L	R
	Male	Female	Male	Female	Male	Female	Male	Female		
Humeral Head Index	p=.0003 F(1,5)= 84.97		p=.08 F(1,5)= 4.48						Black males p=.01 F(3,3)= 26.93 (Humeral Head)	White females p=.006 (Humeral Angle) F(3,11)= 7.23
Humeral Head/Shaft Angle			p=.07 F(1,11)= 3.90	p=.06 F(1,9)= 4.45	p=.05 F(1,8)= 5.20			p=.003 F(1,13)= 13.24	White males p=.07 F(3,3)= 7.4 (Humeral Head)	Black females p=.07 F(3,2)= 13.22
Clavicular/Humeral Index				p=.09 F(1,9)= 3.54					White females p=.03 F(3,11)= 4.35 (Angle)	White males p=.03 F(3,3)= 14.47 (N.P.V.)

<sup>a</sup>Three variables were treated jointly for evidence of morphological effect: humeral head index, angle of humeral head to diaphyseal shaft, clavicular/humeral index. The MANOVA GLM procedure (SAS) was used for the statistical analysis. In "Overall" column, parentheses enclose names of variables which were major contributors to overall effect. Only those variables with  $p \leq .10$  are in the table. Key: N.P.V. = No Particular Variable.

morphological effects was left clavicular curvature, left axillary border-scapular height index, and scapular index. In white males, significant differences are seen in the left scapular index. Significant morphological effects related to scapular index are also seen in black males on the left side, and in black females on the left and on the right. Clavicular curvature, with significant morphological differences in white males (see above) is also significant in white females of this group. The third variable which shows morphological effect is the index of axillary border length to scapular height. This is significant in white males and black females on the left side.

When humeral head index, clavicular-humeral index, and the angle of the humeral head to the shaft were combined in a search for morphological effects, black females and white males show significant effects with no particular variable contributing notably. Humeral head index is the major contributor to overall significant morphological effects in black males. This index was significantly different for the two morphologies in white males as well. The angle of the humeral head gives overall morphological effect in white females on the right side and is individually significant in this group on the left. White females also show morphological effects from this variable, as well as white males, on the left side and black females on the right. The major contributing variable to the overall morphological effects in white females (left side) is clavicular-humeral index.

### Principal Components Analysis--Terry Collection

Six principal components were produced from the raw data for the Terry Collection. The raw measurements were converted to principal components (PA1 option SPSS6--Nie et al. 1975) and no indices were used for this analysis. Twenty variables, 10 from each side, were used. Measurements used, and their abbreviations as presented in Table IV, are: width of the axillary border of the scapula (LWTH, RWTH), length of the border (LAX, RAX), height of the scapula (from inferior angle to superior angle, A-B, Figure 4, page 42--LHT, RHT), breadth of the scapula (from center of rim of glenoid fossa to center of spine on vertebral border, C-D, Figure 4--LBR, RBR), vertical (LHDVT, RHDVT) and transverse (LHDTR, RHDTR) dimensions of the humeral head, angle of the humeral head to the axis of the diaphyseal shaft (LANG, RANG), height of the diaphyseal curve of the clavicle (LCRV, RCRV), maximum length of the clavicle (LCLV, RCLV), and maximum humeral length (LHUM, RHUM).

Table IV presents the principal components matrix, eigenvalues, percent of trace and communality for the Terry Collection.

Component I comprised four variables including scapular breadth, axillary border length, clavicular length and humeral length. The two variables in component II are the vertical and transverse dimensions of the humeral head. Component III is scapular height, component IV the height of the diaphyseal curve of the clavicle, and component V is axillary border width. Component VI is the angle of the humeral head to the axis of the diaphyseal shaft (hereinafter called humeral angle).

TABLE IV

PRINCIPAL COMPONENTS MATRIX, EIGENVALUES, PERCENT OF TRACE AND COMMUNALITY--TERRY COLLECTION

Variables	I	II	III	IV	V	VI	Communality
LWTH	0.10	0.15	0.18	0.16	0.79	0.07	0.73
RWTH	0.10	0.21	0.12	0.13	0.81	-0.04	0.74
LAX	0.78	0.18	0.31	0.01	0.25	0.07	0.81
RAX	0.78	0.17	0.30	0.01	0.27	0.07	0.81
LHT	0.32	0.29	0.81	0.05	0.26	0.01	0.90
RHT	0.27	0.32	0.80	0.01	0.22	0.00	0.87
LBR	0.79	0.37	-0.22	-0.04	0.27	0.03	0.89
RBR	0.78	0.36	-0.28	-0.01	0.24	0.01	0.88
LHLVT	0.21	0.86	0.20	-0.02	0.08	0.06	0.83
LHDTR	0.18	0.85	0.15	0.01	0.23	0.02	0.83
RHDVT	0.27	0.86	0.14	-0.00	0.06	0.07	0.84
RHDTR	0.18	0.87	0.09	0.07	0.17	0.03	0.84
DANG	0.06	0.01	0.00	0.23	0.09	0.79	0.69
RANG	-0.00	0.08	0.01	0.04	-0.06	0.86	0.74
LCRV	0.02	-0.02	-0.06	0.86	0.21	0.13	0.81
LCLV	0.61	0.38	0.19	0.37	-0.12	-0.09	0.71
RCRV	0.08	0.01	0.07	0.88	0.10	0.18	0.82
RCLV	0.57	0.38	0.20	0.39	-0.09	-0.11	0.69
LHUM	0.69	0.23	0.34	0.08	-0.04	0.01	0.65
RHUM	0.53	-0.05	0.23	0.02	-0.13	0.05	0.36
Eigenvalues	4.32	3.89	2.00	1.92	1.87	1.46	
Percent of Trace	21.6	19.5	10.0	10.0	9.4	7.3	

CONDESCRIPTIVE--For Comparison of Means

Table V presents the mean scores for the components. Differences in the mean scores between the races and sexes were tested for significance by Normal Deviate procedures. The results are presented in Table VI.

From Tables V and VI it can be seen that there is a significant difference between the sexes in component I. The variables in component I, however, are all concerned with size and are therefore expected to discriminate between the sexes. Additionally, male scores are larger than female scores in both races. Thus it is clear that males are significantly larger, as expected. Components II, III, and V are also concerned with size and also expected to discriminate between the sexes. Indeed, humeral head measurements (component II) are often used as a principal discriminator of sex in human identification. Component V, axillary border width, is also a variable known to be wider in males and this is seen in these results. Thus it appears that sex differences are basically confined to variables concerned with expected size differences between the sexes.

We also see a significant sex difference in component IV (height of clavicular curve) and this is not a variable that is expected to produce size differences between the sexes. However, this significant difference is seen only in the white group. This may be related to differences between the sexes of the white race with regard to physical exertion. This will be discussed later.

A significant racial difference is seen in component IV between the males (only). White males have greater diaphyseal curvature of the clavicle than black males. No reasonable explanation comes to

TABLE V  
PRINCIPAL COMPONENT MEANS BY RACE AND SEX FOR THE TERRY COLLECTION

	White Males	White Females	Black Males	Black Females
I				
(Scapular breadth, axillary border length, clavicular length, humeral length)	0.519	-0.818	0.995	-0.677
II				
(Vertical and transverse humeral head)	1.415	-1.169	0.986	-1.381
III				
(Scapular height)	0.551	-0.572	0.478	-0.505
IV				
(Height of clavicular curve)	0.564	-0.289	-0.115	-0.279
V				
(Axillary border width)	0.830	-0.462	0.376	-0.855
VI				
(Angle of humeral head to shaft)	-0.151	-0.502	0.742	0.026

TABLE VI

RESULTS OF NORMAL DEVIATE TEST BETWEEN PRINCIPAL COMPONENT MEANS OF POPULATION PAIRS--TERRY COLLECTION

	White x Black Males	White x Black Females	Males x Females White	Males x Females Black
I				
(Scapular breadth, axillary border length, clavicular length, humeral length)	2.12*	.658	6.96**	6.69**
II				
(Vertical and transverse humeral head)	1.87	1.09	12.30***	10.71***
III				
(Scapular height)	0.33	-0.32	5.60**	17.56***
IV				
(Height of clavicular curve)	2.99*	0.05	4.06**	0.82
V				
(Axillary border width)	1.99*	1.97*	6.36**	5.45**
VI				
(Angle of humeral head to shaft)	4.24**	2.36*	1.52	3.77*

These are results of the Normal Deviate test between means:  $N.D. = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$

Levels of Significance: \* = .05; \*\* = .01; \*\*\* = .001.

mind for this difference. However, upon examining the means of the raw data for curvature, it is seen that the difference between the males (mean at 14.3 for whites, 13.4 for blacks--0.9 difference) is far less than the differences between the sexes (2.9 for whites, 2.4 for blacks) for this measurement. Thus the racial difference is relatively weak.

In component VI, there are significant differences between the races and sexes. White males have much lower humeral head angles, thus less cranially deviated humeral heads, than black males. The same relationship exists between white and black females. Males of both races have more cranially deviated humeral heads than females.

#### Discriminant Function Analysis--Terry Collection

The principal component scores were then submitted to a discriminant function analysis (DISCRIMINANT--SPSS6, Nie et al. 1975), where the groups were ventral and Chancelade morphologies. Component VI (humeral angle) was found to be the best discriminator (significance 0.000) between the ventral and Chancelade morphologies. Component I (scapular breadth, axillary border length, clavicular and humeral length--significance 0.001 on left, 0.047 on right) also exhibited reasonable discriminating power between morphologies; and components IV (height of clavicular curve--significance 0.035 on left and 0.01 on right) and II (humeral head dimensions--significance 0.046) on the left side also discriminated between morphologies. Component V (axillary border width) showed significant morphological differences on the left side (0.05). The results for component VI, humeral head angle, were interpreted to mean that scapulae with Chancelade borders

were significantly associated with humeri having more cranially deviated humeral heads (higher angle) and scapulae with the ventral border morphology are frequently associated with lower angled humeral heads (less cranially deviated).

#### General Linear Models--Analysis of Variance--All Groups

Humeral head angle. Table VII shows results of the GLM procedure analyzing the various racial groups studied here, with the addition of data on Arikara American Indians (see Dittner 1976). On the left side, significant differences between the races (0.004) and sexes (0.0007) are seen as well as for morphology (0.002). Significant racial (0.056) and sexual (.09) differences, however, diminish on the right side, but morphological differences remain very significant (0.0001). Thus, the Chancelade morphology is significantly associated with more cranially deviated humeral heads (high angle) on both sides of the body. This association of more cranially deviated humeral heads with the Chancelade morphology is stronger on the left side.

Clavicular curvature. The index of clavicular curvature was another area where significant morphological differences are seen in the MANOVA results. In discriminant function analysis of the principal components (see above) for the Terry Collection, a significant component is the height of the diaphyseal curve of the clavicle. Results of the GLM analysis show significant (see Table VIII) morphological differences for the index of clavicular curvature on the left (0.013) and right sides (0.056). Statistically significant differences are found between the races and sexes on both sides, as

TABLE VII  
MEANS FOR THE HUMERAL HEAD ANGLE FOR SIX GROUPS

	Left Side					Right Side					Overall
	By Race	By Sex		By Morphology		By Race	By Sex		By Morphology		
		M	F	Vent.	Chancelade		M	F	Vent.	Chancelade	
Eva											
Archaic American Indians	47.32 (6.86)	49.79 (6.30)	43.20 (7.33)	45.67 (5.53)	50.14 (8.38)	45.65 (8.07)	46.80 (7.92)	44.29 (8.19)	40.40 (7.23)	44.29 (7.60)	46.49
Averbuch											
Mississippian American Indians	46.71 (6.30)	48.13 (4.95)	45.43 (7.09)	45.07 (7.03)	48.28 (5.17)	43.84 (7.10)	44.69 (6.70)	43.05 (7.41)	43.54 (9.23)	43.90 (6.29)	45.28
Arikara											
Protohistoric American Indians	43.69 (3.91)	44.00 (4.05)	43.44 (3.83)	42.53 (3.68)	45.52 (3.60)	42.83 (3.98)	43.37 (4.32)	43.22 (3.70)	42.39 (3.80)	43.22 (4.24)	43.26
Eskimo	47.03 (4.11)	47.30 (2.64)	46.67 (5.77)	45.83 (4.29)	49.00 (3.16)	45.80 (4.73)	46.11 (4.69)	45.88 (4.87)	43.57 (4.16)	46.50 (4.88)	46.42
Black Americans	45.47 (6.17)	48.56 (6.14)	42.25 (5.88)	42.83 (5.95)	47.81 (6.68)	45.51 (5.39)	47.76 (4.95)	43.17 (4.88)	42.62 (4.52)	47.68 (5.01)	45.49
White Americans	42.50 (5.83)	43.89 (5.13)	41.11 (5.99)	39.48 (4.44)	45.52 (5.53)	42.50 (5.85)	44.56 (5.09)	40.44 (5.91)	38.89 (4.79)	46.11 (4.43)	42.50
Grand Means	45.20	46.67	43.67	43.33	47.34	44.19	45.25	43.08	41.63	45.64	44.91

Key: Figures in parentheses are standard deviations.

seen in Table VIII. When morphological differences are examined group by group, it is found that higher indices of clavicular curvature are invariably associated with scapulae bearing the Chancelade morphology on the axillary border. The mean index associated with Chancelade morphologies is 9.86 while the mean index associated with ventral morphologies is 8.98. Thus more greatly curved clavicular are found in association with the Chancelade morphology on the axillary border.

Scapular index. Scapular index discriminated between the morphologies in the Terry Collection and is found to have borderline discriminatory powers in the other groups studied. Morphological significance is .06 on the left and .08 on the right. Sexual significance is indicated on the right at .003.

Axillary border/scapular height index. Significant differences between the races (0.001) and sexes (.024) is indicated for the index of axillary border length to the height of the scapula. However, on closer inspection, it was seen that only Eskimos were significantly different from the three other groups analyzed (for this index, necessary data were available only for Eskimos, and black and white Americans). The mean index for blacks is 89.45, for whites 89.17 and for Eskimos 82.73. Means for the sexes are: males 85.93 on the left, 85.98 on the right; for females 88.58 on the left, 88.83 on the right. No morphological significance was indicated on the left, but the right side was borderline with 0.08.

TABLE VIII  
MEANS FOR CLAVICULAR CURVATURE INDEX FOR SIX GROUPS

	Left Side					Right Side					Overall
	By Race	By Sex		By Morphology		By Race	By Sex		By Morphology		
		M	F	Vent.	Chancelade		M	F	Vent.	Chancelade	
Eva											
Archaic American Indians	9.29 (1.72)	9.72 (1.71)	8.79 (1.68)	8.81 (1.52)	10.09 (1.64)	9.96 (1.65)	10.39 (1.52)	9.60 (1.66)	9.11 (1.37)	10.27 (1.59)	9.63
Averbuch											
Mississippian American Indians	9.95 (1.66)	10.50 (1.72)	9.43 (1.46)	9.47 (1.76)	10.49 (1.33)	10.68 (1.62)	10.97 (1.67)	10.34 (1.49)	10.61 (1.39)	10.69 (1.61)	10.32
Arikara											
Protohistoric American Indians	9.52 (1.44)	9.46 (1.52)	9.58 (1.38)	9.25 (1.20)	9.95 (1.68)	9.51 (1.32)	9.25 (1.20)	9.73 (1.19)	9.20 (1.20)	10.00 (1.38)	9.52
Eskimo	8.95 (1.68)	9.19 (1.49)	8.57 (1.00)	8.87 (1.84)	9.36 (1.14)	9.42 (1.47)	9.35 (1.42)	9.33 (1.59)	9.28 (1.08)	9.46 (1.61)	9.44
Black Americans	8.06 (1.54)	8.53 (1.60)	7.58 (1.30)	7.85 (1.69)	8.25 (1.39)	8.30 (1.64)	8.70 (1.55)	7.89 (1.67)	7.83 (1.64)	8.66 (1.58)	8.18
White Americans	9.05 (1.62)	9.67 (1.80)	8.43 (1.14)	8.42 (1.33)	9.68 (1.65)	9.33 (1.68)	9.72 (1.84)	8.94 (1.43)	8.75 (1.35)	9.92 (1.79)	9.19
Grand Means	9.34	9.64	9.01	9.00	9.70	9.67	9.87	9.46	8.98	10.01	9.38

Key: Figures in parentheses are standard deviations.

Humeral head index. Another index which was significantly different for the two morphologies in the MANOVA results was the index of the humeral head. In the GLM procedure using all groups, morphological significance is not indicated. However, upon examining the means, there are differences on both sides between the means of indices associated with the two morphologies (ventral 93.46, Chancelade 94.18) and it is in the "expected" direction. This will be discussed later.

### CROSSTABS

Terry Collection. Results of program CROSSTABS (SPSS6--Nie et al. 1975) showed that morphologies were similarly distributed in both races of the Terry Collection. In Table IX it can be seen on the left side that the ventral pattern is exhibited in more than half to two-thirds of the cases, and the Chancelade in less than half of the cases. The opposite is true on the right side for blacks and whites. The Chancelade pattern is seen in two-thirds to three-fourths of the cases and the ventral in one-third to one-fourth of the cases. ---

Concerning sex distribution, there is a greater incidence of ventral morphologies on the left side for females than males. On the right side, the sexes are more evenly matched so that the Chancelade pattern is seen in three-fourths of the cases in both races and sexes.

On examining the age distributions (Table IX), there is generally a decrease in the incidence of the ventral pattern between the youngest group (18-30 years old) to the oldest group (over 40) in both blacks and whites; with a corresponding increase in the Chancelade

TABLE IX  
MORPHOLOGICAL DISTRIBUTIONS FOR BLACKS AND WHITES

Left		Right	
Ventral	Chancelade	Ventral	Chancelade
By Race			
Blacks			
56.8%	43.2%	25.9%	74.1%
(46)	(35)	(21)	(60)
Whites			
66.0%	34.0%	31.9%	68.1%
(62)	(32)	(30)	(64)
By Sex			
Males			
52.8%	47.2%	25.8%	74.2%
(47)	(42)	(23)	(66)
Females			
70.9%	29.1%	32.6%	67.4%
(61)	(25)	(28)	(58)
By Age			
18-30			
77.8%	22.2%	48.9%	51.1%
(35)	(10)	(22)	(23)
30-40			
64.2%	35.8%	17.9%	82.1%
(43)	(24)	(12)	(55)
40-			
47.6%	52.4%	27.0%	73.0%
(30)	(33)	(17)	(46)

Results of program CROSSTABS (of SPSS). Figures in parentheses are numbers of individuals.

morphology with advancing age. An exception to this rule occurs in the whites (on the right) where a quantum jump in the frequency of Chancelade patterns takes place between the youngest group (51%) to the middle-aged group (82%); but there is a slight decrease for the oldest group (73%).

Eva, Averbuch, Eskimos. Similar patterns of distribution are seen in the Eva, Averbuch, and Eskimo groups, as displayed in Table X. In each of these groups, more than half of the left scapulae have the ventral pattern, and two-thirds to three-fourths of the right scapulae have the Chancelade pattern.

The distribution for the sexes in Eva and Averbuch is similar to the Terry Collection in that females generally have slightly greater frequencies of ventral patterns and males have greater frequencies of the Chancelade pattern (and smaller frequencies of the ventral) on the right side, and the opposite is true for the left side. The Eskimo sex distribution is far more equitable than the other groups studied. There will be further discussion on the reasons for this.

The general increase of the Chancelade pattern with age (and the concurrent decrease of the ventral) is also seen in these groups, as they are in the Terry Collection. The most notable jump in frequency occurs between the youngest and middle-aged groups.

When these three American aborigine groups are combined, it is found that 56.3% have the ventral and 43.7% have the Chancelade pattern on the left side; while 22% have ventral and 77.8% have the Chancelade on the right side. The distribution for the sexes for the combined groups is: on the left 47.8% of males have ventral and 52.2%

TABLE X  
MORPHOLOGICAL DISTRIBUTIONS FOR EVA, AVERBUCH AND ESKIMOS: RACE, SEX, AGE

	Eva				Averbuch				Eskimos			
	Left		Right		Left		Right		Left		Right	
	V.	CH.	V.	CH.	V.	CH.	V.	CH.	V.	CH.	V.	CH.
By Race	64.4% (65)	35.6% (36)	29.5% (31)	70.5% (74)	51.1% (90)	48.9% (86)	17.6% (31)	82.4% (145)	57.1% (56)	42.9% (42)	22.4% (22)	77.6% (76)
By Sex	Male											
	50.0% (28)	50.0% (28)	13.8% (8)	86.2% (50)	40.4% (36)	59.6% (53)	9.8% (9)	90.2% (83)	56.9% (29)	43.1% (22)	18.5% (10)	81.5% (44)
	Female											
	82.2% (37)	17.8% (8)	48.9% (23)	51.1% (24)	62.1% (54)	37.9% (33)	26.2% (22)	73.8% (62)	57.4% (27)	42.6% (20)	27.3% (12)	72.7% (32)
By Age	18-30 yrs.											
	80.6% (25)	19.4% (6)	63.3% (19)	36.7% (11)	84.9% (45)	15.1% (8)	36.2% (17)	63.8% (30)	76.7% (23)	23.3% (7)	48.4% (15)	51.6% (16)
	30-40 yrs.											
	48.7% (19)	51.3% (20)	13.6% (6)	86.4% (38)	35.9% (33)	64.1% (59)	11.2% (11)	88.8% (87)	52.9% (27)	47.1% (24)	13.5% (7)	86.5% (45)
By Age	40 + yrs.											
	67.7% (21)	32.3% (10)	19.4% (6)	80.6% (25)	38.7% (12)	61.3% (19)	9.7% (3)	90.3% (28)	35.3% (6)	64.7% (11)	(0)	100.0% (15)

Results of CROSSTABS Program (SPSS6). Note: V. = Ventral, CH. = Chancelade. Figures in parentheses are numbers of individuals.

have Chancelade, while 66.8% of females have ventral and 33.2% have Chancelade patterned borders. On the right side, males have a 17.7% frequency of ventral and 82.3% of Chancelade patterns; while females have 38.6% frequency of ventral and 61.4% of Chancelade patterned borders. Thus the averages demonstrate that, although both sexes have greater frequencies of the Chancelade pattern on the right, males exhibit slightly greater frequencies of the Chancelade pattern (and slightly smaller frequencies of the ventral patterned borders) than do females.

## CHAPTER IV

### DISCUSSION

Several hypotheses posed at the outset of this study are apparently supported by the results of statistical analyses. Scapulae bearing the ventral morphology exceed those bearing the Chancelade morphology on the left side and the reverse is seen on the right side. It is known that human populations are predominately right-handed (Hrdlička 1942c, Jantz 1964), therefore, one might expect the use of the upper limb to be greater on the right side. Indeed skeletal populations generally show greater bone remodelling or "stoutness" due to greater muscular usage of the bones of the right arm than on the left (Hrdlička 1942c). The findings of this study thus support the hypothesis that the Chancelade morphology is a product of muscular use or exertion in the shoulder area. Previous studies (Dittner 1976, Trinkaus 1977b) also found a greater incidence of the Chancelade pattern on the right side and concluded that morphological differences on the axillary border are a function of use.

For the five groups studied here, the average percent on the right for the Chancelade pattern is 74.5%. On the left side, the incidence of the Chancelade pattern is 40% for all groups. For the males, the average frequency of the Chancelade pattern on the right side is 79.9% and for females it is 66.3%. There is a reasonable difference between the sexes in all five groups, therefore, a closer look at this aspect is warranted.

The largest sex differences are found in the archaic group. Males of the Eva archaic American Indian group have a 35% greater incidence of the Chancelade morphology on the right scapula than the females. This group depended on hunting and gathering for subsistence. Thus, the women were generally engaged in food preparation and gathering while the men were often hunting game (using the atlatl), chopping trees for construction of temporary shelters and other similar activities (Lewis and Kneberg, 1946). In short, it is probable that the use of the upper limb musculature was notably greater for the males than for the females.

A difference of 16% was seen between Averbuch males and females on the right side. This group was involved in horticultural activities as well as some gathering and hunting. Males were probably using upper limb musculature rather strenuously during hunting and war activities using the bow and arrow. The traditional role of females in horticultural societies was in working the fields and gathering. These activities would have required reasonably strenuous use of the upper limbs, and, therefore, not as great a difference exists between the sexes as that which is seen in the archaic group.

Unlike the other groups, little or no difference is seen between the sexes in the Eskimos in morphological frequencies. The subsistence level of the Eskimos studied here required strong use of the upper limbs by men and women: for men in boatmanship and open water hunting and for women as they participated in preparations for hunting trips and carried heavy loads and in preparing hides for various uses (Dumond 1977). Also, role reversal is not uncommon among the Eskimos at times.

Upon surveying the five groups, it can generally be seen that there are greater frequencies of the Chancelade pattern on the right side (especially among the males) in the three societies where technology is less advanced than in the two groups living in modern technological society. There are negligible racial differences between the blacks and whites, the two groups in modern technological society, in the frequency of Chancelade morphology on the right side; however, the frequency for whites is slightly lower than for blacks and is the lowest frequency of all the groups studied (68%). This complies with expectations in that 20th Century American whites are less involved in manual labor than any of the other groups here, including their black contemporaries. Relatively insignificant sex differences are seen in the black group, presumably because American blacks, males and females, are often employed at jobs requiring muscular exertion. This is particularly true of the sample used here. Most of the specimens in the Terry Collection were indigents involved in manual labor, or generally living under very difficult conditions. A 10% sex difference in the whites may be reflective of the lower level of muscular exertion required of white females in our society. Thus the sex differences seen in these groups may be simply related to use of the upper limbs.

There is an increase with age in the incidence of the Chancelade pattern and a decrease of the ventral morphology. As seen in Tables IX and X, pages 65 and 67, respectively, the frequency of the Chancelade morphology is relatively low in the youngest group and is dramatically increased in the middle-aged group. This is seen, for example, at Eva where 18 to 30-year-olds have 36.7% Chancelade

morphologies on the right side and 30 to 40-year-olds have 86.4% of this morphology. These results for age differences further support the hypothesis that the pattern types reflect muscular use of the shoulder region. The muscular demands of physical labor would not be seen osteologically until after some years of stress due to participation in the labor force (Hrdlička 1932, Oxnard 1973).

Some metrical features of the scapula were tested in order to see whether differing proportions of the scapula had morphological effects. Results of the multivariate analysis of variance for scapular index showed that there were significant morphological effects for black females on both sides and for black males and white males on the left side. Significant morphological differences were seen for the index when all groups were analyzed by the GLM procedure; but the races and sexes were also significantly different. Scapulae with the Chancelade pattern had a higher index (67.64) than those with the ventral pattern (65.99); however, the index for females (67.55) was higher than that for males (66.03). It is difficult to reach a conclusion with regard to the influence of scapular index on the morphological types. As the incidence for Chancelade pattern is usually slightly higher for males, the association here of Chancelade scapulae and females with broader scapulae is contrary to basic findings. Vallois (1932) found the scapular index was one of the metrical scapular features which was significant in distinguishing between major human races. Scapular breadths were lowest in New Caledonians, Fuegians, Eskimos and Finns and highest in some North American Indians. Hrdlička (1942a) found sex differences in some racial groups. He concluded that these racial differences are not

logically explained (Hrdlička 1942a). Generally, the results for scapular indices found here seem to add little understanding to this study.

The proportion of the axillary border to scapular height yielded indications of morphological significance when tested by the MANOVA procedure. Significance was most notable for black females (white males at .099 are borderline). When all groups were analyzed, racial and sexual significance, but not morphological significance, was seen. Thus the morphological effects of this index may be questioned. However, axillary border length was one of the four contributors to the significant component I (see Table IV, page 55). It is possible that the length of the axillary border is in some way associated with morphological pattern on the border. Although the ratio of the border to scapular height was morphologically significant mainly on the left side, it should be noted that on the right side the indices associated with the two morphologies are different and in the same direction as on the left side. On both sides, indices are lower when associated with Chancelade scapulae (Chancelade 131.90, ventral 132.43 on right; 129.94 Chancelade, 131.69 ventral on left).

The main factor of interest for the humerus and the leading discriminator between morphologies is the angle of the humeral head to the axis of the shaft. It was found that this factor was significantly different for the races and sexes in the Terry Collection. It was also significant for race and sex in the pooled groups on the left side only, and for morphology on both sides. It is difficult to discern whether racial and sexual differences overrule or overlie morphological significance. Where significant sexual differences exist

it is seen that male humeral heads are more cranially deviated than females. When significant differences exist between races, it is notable that groups known to use greater muscular exertion have more cranially deviated humeral heads than those leading more sedentary lives (e.g., Eskimos and Archaic American Indians have the highest angles, American whites have the lowest--see Table VII, page 61). There is a consistent and significant association of the higher humeral head angle with the Chancelade morphology. This was also found in a previous study on Arikara American Indians (Dittner 1976). In the present study, this association is seen in both sexes on both sides of the body. It is known that the mean humeral head angle of Neandertals was higher than the mean of the angles for modern men (McCown and Keith 1939). It is also obvious that Neandertals used their upper limbs or shoulder region very strenuously (Smith 1976b, Trinkaus 1977b).

Another aspect of the humerus, the index of the humeral head, was analyzed with regard to morphological effects. Morphological significance was seen for this index in the MANOVA treatment of the Terry Collection, but not seen when all groups were treated by the GLM procedure. However, as with other indices above, although overall morphological significance is not indicated, there is a consistent difference seen between the means associated with the two morphologies in all groups and it is in the "expected" direction. It was "expected" or hypothesized that higher humeral head indices would be associated with Chancelade morphologies, as Neandertals had higher indices than modern humans. There may be a slight contribution to morphological effects from this aspect. (The two humeral head

measurements were grouped together in a single component during the course of principal components analysis).

The importance of the influence of clavicular curvature on the morphology of the axillary border of the scapula is difficult to assess. The index of clavicular curvature was significantly related to the Chancelade morphology in a study on Arikara American Indians (Dittner 1978) and showed some significant morphological effects in white males and females of the Terry Collection in multivariate analysis. Univariate analysis of the pooled groups showed morphological significance for the index of clavicular curvature on both sides. Of interest is that the height of the diaphyseal curve of the clavicle (component IV) and the clavicular length (included in component I) had discriminatory function (see Table IV, page 55). When the individual means are scrutinized in the MANOVA results for the Terry Collection, there is always a higher curvature index associated with the Chancelade morphology on both sides in both races. Additionally, in the results of the GLM procedure for all groups one sees in all races, for both sexes and sides and at all ages, that the amount of curvature is almost always markedly greater when associated with the Chancelade morphology (an exception occurs in the Eskimos on the left side where curvature is nearly equal for both morphologies). There is also a consistent relationship of morphologies with regard to sex. In the analysis of all groups, males have slightly higher indices than females. However, no consistent difference in curvature is found between the sexes or races in other studies on the clavicle (Terry 1932).

## CHAPTER V

### CONCLUSIONS AND SUMMARY

#### I. CONCLUSIONS

The results of morphological and metrical investigations suggest that a basic cause of differing morphologies on the axillary border of the scapula is differential muscular use of the upper limb and body. It has been observed in previous studies (Dittner 1976, Trinkaus 1977b) that there is a greater incidence of the Chancelade morphology on the right side. The results of the present study are in agreement with these findings. An average of over 70% of right scapulae have the Chancelade pattern. It is known that in most populations, over 90% of the individuals are right-handed. As the expected frequency with regard to morphological patterns should be approximately a 50-50 distribution with respect to side, the indications are that morphological changes occur as a result of greater use or exertion. The results also show an increase with age in the incidence of Chancelade axillary border morphologies in the populations studied. In the middle-aged group, 30 to 40-year-olds, there is an average increase of nearly 40% in the incidence of Chancelade patterns (on the right side) over the incidence found in the youngest groups. The assumption is that the effects of muscular exertion necessitated by entrance into the regular work force are not seen until one has been involved in these labors for a period of time (Oxnard 1973).

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Bainbridge and Genoves (1956) and Vallois (1932) also support the argument that the Chancelade morphology is indicative of greater exertion in the shoulder area. Von Eickstedt (1925) and Vallois (1932) found much greater incidences of Chancelade-type borders among non-technologically advanced groups. One expects that greater physical exertion is necessitated by the lifeways of these groups than is necessary in technologically advanced societies. Conversely, modern European groups generally exhibit smaller frequencies of Chancelade axillary borders.

Differences in frequencies of the Chancelade type were found between the sexes in the groups studied. There were consistently higher frequencies of the Chancelade pattern for males on the right side. The amount of difference varied among the groups, and the variability seemed to be commensurate with the differential in the sex roles of the group.

The hypothesis that muscular use or exertion in the shoulder region has an influence on the morphology of the axillary border seems to be supported by these findings insofar as the formation of the Chancelade morphology is concerned. However, the question remaining is why the Neandertal morphology is rarely, if ever, seen on anatomically modern man, even in societies where the "exertion" level may be similar to that of Neandertals.

In a functional analysis of the raison d'etre of the Neandertal type of axillary border, Trinkaus (1977b) maintained that the teres minor muscle was more greatly developed in Neandertals because it assisted in resisting the powerfully developed deltoid muscle of Neandertals while maintaining the humeral head in the

glenoid fossa during abduction. It is known that Neandertals had powerful deltoid muscles, as enlarged deltoid tuberosities are found on Neandertal humeri (Endo and Kimura 1970). This point of the interpretation may be questioned, as subscapularis (the ventrally inserted muscle) also aids in providing the force tending to pull down the humeral head along with teres minor and infraspinatus (Morris and Schaeffer 1953). Subscapularis, infraspinatus and teres minor are a "muscle force couple" which act continuously as a functional group during abduction as depressors of the humeral head while supraspinatus and deltoid are elevating the humerus (Inman et al. 1944, Johnston et al. 1958).

Trinkaus does say, however, that this resistive action against deltoid is not in itself sufficient to explain the apparently greater development of teres minor in Neandertals. The teres minor muscle, infraspinatus, and posterior fibers of the deltoid muscle act as lateral rotators of the humerus (Johnston et al. 1958) and in this role teres minor had to resist the strongly developed medial rotators of the humerus: latissimus dorsi, pectoralis major, and teres major. These muscles are also the primary humeral adductors. The medial rotation of these muscles during adduction was necessarily counter-balanced by strengthened lateral rotators in order that a precise yet powerful humeral adduction takes place. Greater use of infraspinatus by Neandertals is also indicated, by the very deep infraspinatus fossae noted by Heim (1974) in the La Ferrassie specimens. It appears that both teres minor and infraspinatus were used heavily. However, the subscapularis fossae were also well developed in these specimens, suggesting that subscapularis was also greatly developed. However,

this muscle may not have been quite as heavily stressed in Neandertals as it is expressed in only one-third of Neandertal scapulae; that is, it occupied one-half of the border in the bisulcate type. It is possible that the origins of this muscle may have shifted slightly due to the scapular shift on the thorax. One is reminded of Vallois' (1932) statement that the most external fascies of subscapularis differentiate one in eight times into a special muscle which is a subscapularis accessory muscle. Thus it is perhaps a matter of emphasis or de-emphasis of the accessory muscle that differentiates the expression. With this in mind, we return to von Eickstedt's speculation (1925) that there is an evolutionary change in the muscles themselves as well as shifts of emphasis or stress due to the flattening of the rib cage and resultant shifts in relationships. There may have been shifts in the particular muscle fibres attached to specific places on the axillary border. This may (or may not) have been related to the changing thorax shape.

It appears logical that the shape of the Neandertal thorax was a crucial factor influencing the morphology of the axillary border of the scapula. The shape of the thorax in Neandertals was different from that of modern humans, and this difference may have altered the relationships between bones and muscles in the shoulder region. The barrel-shaped thorax is indicated by the fact that curvature of the ribs is less pronounced in Neandertals than in modern hominids (Hrdlička 1930, McCown and Keith 1939, Endo and Kimura 1970), and the shape of the thorax may be gauged by the index of clavicular curvature (Hrdlička 1930). In a previous study of Arikara American Indians (Dittner 1978), as well as in the present study, a positive

relationship was seen between a higher clavicular curvature index and the Chancelade morphology.

The Neandertal scapula was probably positioned slightly differently with respect to the rib cage which altered its position relative to the humerus. This differing orientation between the scapula and the humerus may have altered the amount of stress of certain muscles in the scapulohumeral group. In this study, the positive relationship of the more cranially deviated humeral head with the Chancelade morphology may be indicative of the morphological influence of altered scapulohumeral relationships. The deviated angle and the wider humeral head of Neandertals may have contributed to the creation of dorsal sulci in this group [a positive relationship between the Chancelade pattern and wider humeral heads, i.e., larger indices, was found in this study]. Alternatively, the cranially deviated and wider head may have been a result of the particular scapulohumeral juxtaposition resulting from the shape of the rib cage; or the pre-existing humeral head orientation may have made an additional contribution to the musculoskeletal shifts in emphasis. With the shifting of the scapula's position on the chest wall the positioning of the humerus was affected, as the humerus would have followed the scapular shift (Inman et al. 1944). These changes and shifting relationships are somewhat analogous to those that occurred in the upper body during primate evolution (from ape to man) with the erect posture evolving concurrently. In addition, these changes in the thoracic region may, in turn, have induced other developments such as, for example, the increase in humeral torsion found in progressing through the primate order from monkeys, through the apes, to man (Krahl and Evans 1945). Neandertals

fit into this sequence by having slightly weaker humeral torsion than modern hominids (Howell 1957). It may someday be confirmed that many Neandertal anatomical tendencies fit into an evolutionary course. Dorsal grooving of the scapular axillary border would probably be seen on the Homo erectus and Australopithecus scapula, if this area of the bone is ever found [although, if australopithecines were part-time brachiators while perfecting bipedalism (Ciochon and Corruccini 1976), their scapular borders may be more similar to modern apes].

The Neandertal scapula and shoulder joint is probably at an intermediate evolutionary stage between Homo erectus and Homo sapiens sapiens. The mosaic nature of human evolution would have allowed the lower limbs to precede the upper in advancement toward the modern human condition. "The relationship between function and morphology may exhibit a certain degree of time lag" (Oxnard 1973). Changes in the cultural or technological level often precede and stimulate biological evolution. It is expected that the morphology of Neandertal upper limb bones would be on an earlier point in the continuum of development than that of anatomically modern hominids.

One must also consider the specific demands of the cultural adaptive level and what these demands might mean in terms of how the muscles were used. The earlier discussion concerning muscle usage considered the level of general muscular exertion which might be necessitated by a harsh way of life. General robustness of the Neandertal skeletal material attests to this way of life. The subsistence pattern of Neandertals may have demanded not only greater biomechanical stress at the shoulder joint but also habitual kinds of movements which changed or became unnecessary in later levels of

cultural adaptation. Vallois (1932) suggested that, since one of the functions of the teres minor muscle is to rotate the humerus laterally, perhaps certain aspects of the Neandertal culture necessitated more frequent or more strenuous use of the lateral rotators than in modern hominids. This theory complements the earlier explanation by Trinkaus (1977b) concerning the stronger use of the lateral rotators in order for precise and powerful adduction to take place.

The speculation in this work is that an habitual way of using certain tools or weapons in the Middle Paleolithic (and possibly earlier, as well) may have influenced stronger development of the teres minor muscle. For example, a particular way of heaving or using a spear may have differed from later usage and may have emphasized the teres minor muscle; or, the morphology of the thorax area may have necessitated stronger development of teres minor in order that the weapon be properly heaved. The advent of the spear throwers or atlatl in the Upper Paleolithic may have diluted the necessity for strong use of certain shoulder muscles in hunting and other activities.

The results of functional studies reported here support the idea that extensive use or stress of the teres minor muscle causes the bisulcate (Chancelade) morphology; and, that use plus the extreme shape of the Neandertal thorax contributed to the high frequency of the dorsal sulcus in Neandertals. However, there may be a genetic component involved as well. That is, there may be selection for the Chancelade morphology in modern populations where heavy use of the upper limbs is necessary, and there may have been selection for the Neandertal morphology in the Middle Paleolithic. Thus, individuals with potentially stronger scapulae (thicker, more laterally turned,

more attachment area for teres minor) would have better potential for performing strenuous tasks and be better equipped for a rugged way of life.

Hrdlička (1942a:77) noted that there is a tendency to a particular form of bone being inherited with "the result subject to functional modification." Roberts concludes that the morphology of the scapula has a genetic basis," but is dependent to a large degree on secondary influences during ontogenetic development, including the stresses imposed by its associated musculature" (1974:198).

Upon investigating juvenile scapulae it was seen that many have a vague appearance of a tendency toward a ventral sulcus; some few, however, appeared as though a bisulcate pattern was a possibility for later development.

Many authors agree that there is strong genetic control of trait expression (Berry 1975), but certain non-metric, or discrete, traits may also be influenced by environmental stress and may also be related to age or sex (Corruccini 1974). However, as Corruccini points out, it is difficult or impossible to test by experiment precise proportional contribution of the genotype to discrete skeletal traits.

The evidence points to multifactorial contributions. It has been suggested that traits solely under genetic control would be equally expressed bilaterally; and conversely, would be asymmetric if environmental stress is contributive (Garn et al. 1966, Trinkaus 1978b). The most important environmental force would be biomechanical stress. Certain non-metric traits, such as tibial retroversion, are known to be variable as a result of biomechanical forces. This is

expected, as it is known that bone responds to normal or abnormal biomechanical stress by remodelling (Tschantz and Rutishauser 1967). Thus the occurrence of asymmetry would indicate that asymmetric stress had been in force upon the skeletal structures.

Whether the cause of the morphology is predominately functional or genetic, the differing morphologies on the axillary border do not affect the functioning of the shoulder region. In studies of discrete traits in mice, mutations may lead to sharp defects on the scapula; yet the forelimbs perform normally (P. Selby, personal communication). We do not see notable differences in modern hominids in the functioning of the shoulder region, yet there are morphological differences on the bones involved. Neandertals were undoubtedly able to perform all necessary tasks using the upper limb in a similar manner to all Upper Paleolithic hominids and all anatomically modern hominids that followed.

## II. SUMMARY

It appears that several anatomical features of the shoulder region combine to influence the morphology of the axillary border of the scapula in modern hominids. The primary cause of morphological change is exertion in the shoulder region. Other features of the shoulder and thorax, more extreme in (most) Neandertals, combined with strenuous use of the upper limb by Neandertals to produce a different morphology. Paralleling the gradual morphological changes on the border through time, from dorsal to bisulcate to ventral morphologies, were the flattening thorax, the laterally shifting humeral head (relative to the shaft), and the reducing of the demands

upon the upper limb musculature. The technological advances which influenced this last factor may have also contributed to changes in the habitual manner of rotation of the upper limb which produced differential stress on the muscles. Genetic selection for a border able to sustain the stresses of a harsh environment may have also contributed to the high frequency of the unusual morphology of the Neandertal axillary border.

The suggestion that Neandertals were not directly ancestral to modern hominids due to the fact that the axillary border was so different from recent humans seems untenable. This idea seems especially untenable when one considers that the Chancelade (bisulcate) pattern is seen on one-third of Neandertal scapulae, most Upper Paleolithic scapulae, and in reasonable frequencies on the scapulae of contemporary hominids. Thus it seems that the gradual transition of morphological types on the axillary border of the scapula fits well into the general evolutionary scheme from Neandertals to anatomically modern hominids.

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## VITA

Carol Baratz Dittner-Plasil was born and raised in New York City. She attended William Cullen Bryant High School in Queens, New York. She received the Bachelor of Arts degree in 1958 from Queens College of the City University of New York with a major in Education and a minor in Psychology. While an undergraduate, she became a member of the honor societies of Sigma Chi and Psi Chi, as well as the service sorority, Gamma Sigma Sigma. She is a member of the honor society Phi Kappa Phi, as well as the American Association of Physical Anthropologists and the Tennessee Anthropological Association.

Carol began her graduate work in Anthropology at The University of Tennessee in the fall of 1971. From September of 1972 to September of 1973, she and her family resided in Mainz, Germany. Carol spent that year attending lectures in the Institutes of Prehistory and Anthropology at the University of Mainz, in addition to travels in many European countries. With the return of the family to Tennessee in 1973, she resumed her graduate studies at The University of Tennessee, Knoxville. The Master of Arts degree with a major in Anthropology was awarded in June 1976.

She is married to Dr. Franz Plasil, a nuclear physicist, who is a group leader and senior research staff member at the Oak Ridge National Laboratory. The couple live in Oak Ridge and have four children: Amy and Steven Dittner, and David and Maia Plasil.