DEVELOPMENTAL ANOMALIES OF THE VERTEBRAL COLUMN, RIBS, AND EXOCCIPITALS IN THE HUMAN SKELETAL REMAINS FROM TWO CEMETERIES IN ENGLAND: ST. AUGUSTINE THE LESS, BRISTOL AND THE QUAKER BURIAL GROUND, KINGSTON-UPON THAMES

MINDY CHRISTINA PITRE

NOTE TO USERS

Developmental Anomalies of the Vertebral Column, Ribs, and Exoccipitals in the Human Skeletal Remains from Two Cemeteries in England: St Augustine the Less, Bristol and the Quaker Burial Ground, Kingston-upon Thames

by

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ABSTRACT

The examination of skeletal material allows for a greater understanding of the conditions to which historic and prehistoric populations were exposed. Even more specifically, the analysis of defects occurring during the process of human skeletal development may be used to reveal aspects of human biology, culture, and environment.

Eighty-one skeletons from the St Augustine the Less church, Bristol England (1240-1956 A.D.) and the Quaker burial ground, Kingston-upon Thames, England (1663-1814 A.D.) were thoroughly examined for the presence of developmental defects of the vertebral columns, ribs, and exoccipitals. The skeletal remains from the Quaker and St Augustine samples offered a potential opportunity to study defect frequencies respectively in an isolated and assorted gene pool. This research documents the presence, location, and frequency of developmental defects, which provides a mechanism for understanding the conditions to which these populations were exposed.

Little variation was found in the incidence of defects between both collections. This evidence was used to suggest that both groups originated from a similar gene pool where differences in defect patterns may be attributed to genetic distance. Because of a general absence of nutritionally-derived traits, it was suggested that individuals from both archaeological samples probably led reasonably healthy lives. Furthermore, differences in social and marriage patterns between both groups did not seem to have an effect on overall defect frequencies.

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CHAPTER 1: INTRODUCTION

"The pattern of disease or injury that affects any group of people is never a matter of chance. It is invariably the expression of stresses and strains to which they were exposed, a response to every-thing in their environment and behaviour."

Wells, 1964:64

Using the methods of paleopathology, anthropologists obtain information concerning the health, disease, and lifeways of ancient populations. This information is obtained through the study of human skeletal remains. With this data, paleopathology offers a look at the conditions to which ancient populations were exposed. Aspects of human biology, culture, environment, and disease may be revealed through the study of various paleopathologies. Paleopathologists examine human remains for evidence of trauma, metabolic and nutritional disease, congenital disorders, and infectious disease to name a few. The present research focuses on congenital disorders, i.e., those caused through errors during the process of human development (morphogenesis).

1.1 BACKGROUND OF STUDY

The potential for pathology begins with the first moment of development. Human development is a complex operation beginning first with an undifferentiated mass known as an embryo. Following a series of events, the spinal column is formed, providing support for the body and protection of the spinal cord. This structure generally consists of thirty-three vertebral segments - seven cervical, twelve thoracic, five lumbar and sacral, and four

coccygeal (Abrahams et al., 1998). The vertebral column articulates with the base of the skull at a location referred to as the exoccipitals- a region including the occipital condyles and foramen magnum (Barnes, 1994). Flanking each side of the thoracic vertebrae are normally twelve pairs of ribs. Errors in the development of these areas are not uncommon, leading to the formation of defects. Anomalies may develop within the fetus *in utero*, inherited through gene transmission or caused by a stimulus during development when structures are vulnerable (Bland, 1994:417).

Both genetic and environmental factors have been implicated in causing developmental defects of the vertebral columns, ribs, and exoccipitals of experimental animals (e.g., Searle, 1954; Saegusa et al., 1996) and humans (e.g., Harris, 1959; Martínez-Frías, 1994; Innis, 1997; Martínez-Fríaz et al.,1998). An estimated 25% of developmental defects are genetic in origin, and this percentage continues to rise with developments in technology and advances in genetic research (Bland, 1994:417). Genetic abnormalities have been classified as either being chromosomal (i.e., groups of genes) or single gene disorders (Jeffreys, 1980:32). Environmental forces affecting development include drugs, radiation, metabolic abnormalities, nutrition, infection, and most probably environmental pollutants (Bland, 1994:417).

Typically within the anatomical and physical anthropological literature, the more obvious and extreme developmental anomalies affecting the vertebrae, ribs, and exoccipitals are recorded in small numbers (e.g., spina bifida, accessory ribs, block vertebrae)(Barnes, 1994:1). However, more extreme cases are rarely discovered since

those suffering them usually die soon after birth and fetal and newborn remains do not preserve well. These defects have been recognized in the anatomical literature since 1874 (Belamy, 1874-75), and research concerning their significance on the skeleton continues today (e.g., Martínez-Frías, 1994; Innis, 1997; Martínez-Fríaz et al., 1998).

Cases of developmental defects have been noted within the paleopathological literature occurring on both historic and prehistoric skeletons (e.g., Allbrook, 1955; Martin, 1960; Bradtmiller, 1984; Anderson,1989). Defects mentioned within the paleopathological literature include (a) spina bifida occulta (e.g., Bennett, 1972), (b) numerical variation in vertebrae (Bornstein and Peterson, 1966; Kaufman, 1974), (c) butterfly vertebrae (Brasili et al., 2002), (d) cervical ribs (Denninger, 1931), and (e) rib abnormalities (Martin, 1960). However, Barnes (1994) carried out the first comprehensive study recognizing the importance of focussing on the more subtle developmental anomalies of the axial skeleton. This is important since despite severity, many defects arise from similar etiologies. Therefore, minor defects can be representative of more severe ones. Following Barnes' (1994) publication, several researchers have applied her morphogenetic framework in recognizing the importance of development when classifying defects (e.g., Usher and Christensen, 2000).

Patterns of defect formation have been used in several ways. Because many of these traits travel along family lines, they may be used to reveal the type of marriage practises followed by a group. A similar developmental pattern of defects can be used to suggest a common gene pool whereas variable expression suggests cultural influences in

the form of marriage and residence patterns (Barnes, 1994:28). For example, Kennedy (1981) discovered lower genetic variability within the males of the Maritime Archaic Indians of the Port au Choix-3 locus II cemetery, Newfoundland (4400 - 3300 B.P.) compared to the females when studying metric and non-metric traits. Within this society, males experienced higher incidence of similar defects whereas females presented more variation in types of traits. Kennedy (1981) suggested that the residence units of the Maritime Archaic Indian bands were based on male-male ties (patrilineal), where females were brought in from other bands for marriage. Therefore, trait frequencies or gender ratios can be used to complement other skeletal data to suggest marriage patterns or residence units within a prehistoric population such as this, where ethnographic sources and historical documents do not exist.

A higher incidence of certain nutritionally-derived traits may also suggest deficiencies in essential elements such as selenium, zinc, and folic acid during pregnancy (Zimmerman and Lozzio, 1989). For example, Dickel and Doran (1989) discovered a high prevalence of neural tube defects in the skeletons of several individuals from the Windover Site (7000 B.P.), a middle Archaic population from Florida. A high incidence of these traits was used to suggest that individuals from this population suffered from deficiencies in the aforementioned elements leading to the high incidence of more severe neural tube defects.

Moreover, the presence of minor defects can lead to interpretations concerning the prevalence of major defects, since they may be of similar etiology. This is important since

the presence of severe defects in archaeological populations is generally under-represented because of ensuing mortality and poor preservation of subadult remains. Barnes (1994) used the prevalence of minor defects to suggest that more major manifestations of the traits may have been present on skeletons of the Puye and Central Pajorito Plateau populations. Following Barnes (1994), during the analysis of the Maritime Indians of Port au Choix, Newfoundland (4400 - 3300 B.P.), I discovered several varieties of mild developmental defects (Pitre, 2003). This data was used to suggest that the Maritime Archaic Indians of Port au Choix may have presented more severe manifestations of these traits which are known to result from similar etiologies.

1.2 PURPOSE OF THE RESEARCH

This research is an interpretation of the osteological and paleopathological data collected from the skeletal remains of both the Quaker burial ground, Kingston-upon Thames, England and the St Augustine the Less church, Bristol England. Between the years of 1663-1814 A.D., members of the Quaker organization were buried within the grounds surrounding the meeting house at London Road, Kingston-upon Thames. In 1996, prompted by recent development, the land once used by the Quakers as a cemetery for over one hundred and fifty years was subject to archaeological excavation (Kirk, 1998:303). A total of 360 skeletons were recovered. Similarly, the parish church of St Augustine the Less located in Bristol, England (1240-1956 A.D.) contained the skeletons of its members for over 700 years of use. In 1983, also because of looming development,

the skeletons of 119 individuals were removed from this cemetery (Boore, 1998:67). Both skeletal collections are currently held within the School of Conservation Sciences at Bournemouth University, Bournemouth, England.

The purpose of this research was twofold. The first goal of this research was to inventory and catalogue developmental defects in both skeletal collections using an adaptation of Barnes' (1994) morphogenetic framework. This framework was chosen since, in order to determine the pattern of developmental defects within both populations, it was important to understand their development and to recognize their variable expressions. The second goal of this study was to use this information to attempt to put each individual within the framework of their local population, to provide potential clues concerning the genetic and social structure of the individuals buried within the Quaker and St Augustine the Less grounds. Therefore, the purpose of this research was not to contribute additional suggestions as to the causes of these conditions, but to report the occurrence of defects affecting the exoccipitals, columns, and ribs of two small collections from Bristol and Kingston-upon Thames, England.

A total of 81 skeletons were analysed from both the Quaker (1663-1814 A.D.) and St Augustine the Less (1240-1956 A.D.) collections. During the analysis, emphasis was placed on the more subtle and less documented developmental anomalies of the vertebral column, ribs, and exoccipitals since they are likely more visible within the skeletal record. For this research, both skeletal samples were particularly interesting in terms of expected defect frequencies. Members of the Society of Friends (Quakers) are known to have been

encouraged to marry within the organization whereas parishioners of the St Augustine the Less church are believed to have originated from diverse genetic backgrounds (Start and Kirk, 1998 and O'Connell, 1999). Therefore each collection offered an opportunity to study defect frequencies in an isolated and assorted gene pool respectively. As a result, it was anticipated that Quaker skeletons would present more similar and numerous defects compared to the skeletons of the parishioners of the St Augustine the Less church. The skeletons of members of the St Augustine the Less church were expected to present an array of developmental conditions, the opposite effect of an isolated gene pool.

The following chapter will provide an introduction to normal skeletal development and the timing and appearance of inborn errors affecting the growth of the vertebral column, ribs, and region of the exoccipitals. Furthermore, both a review of the literature and specific cases of these traits that have been reported within both the anatomical and paleopathological literature will be presented. Chapter 3 will provide a historical background concerning both the Quaker and St Augustine the Less skeletal collections. A general overview of all archaeological and osteological work involving both collections will also be presented. Chapter 4 will provide a comprehensive review of the methodology carried out within this research. Following the presentation of the methodology, Chapter 5 will bear the results recovered following the analysis of both skeletal collections. Chapter 6 will contain a discussion concerning the overriding implications of the data and a paleopathological interpretation of the results. Finally, Chapter 7 will provide general conclusions and a direction for future study.

CHAPTER 2: DEVELOPMENT OF THE VERTEBRAL COLUMN, RIBS, AND REGION OF THE EXOCCIPITALS

2.1 NORMAL DEVELOPMENT

Development is a complex process. Defects of the vertebral column, ribs, and exoccipitals develop during the early stages of morphogenesis. The crucial stages of human development during which most defects arise are the blastemal/mesenchymal, chondrification, and ossification stages (Arey, 1965:405; Barnes, 1994:14; Heggeness, 1995:39). During the blastemal stage, the precursors of several cellular bodies are produced (Barnes, 1994). Chondrification is the conversion of these mesenchymal tissues into cartilage. Similarly, ossification involves the conversion of the blastemal/mesenchymal precursors or the cartilage models into bone (Heggeness, 1995:39).

Normal skeletal development depends on the timing of each of these crucial stages. Occasionally, development does not follow the normal pattern, leading to the formation of a defect. Three classes of developmental anomalies have been observed on skeletal material within the vertebral column, ribs, and exoccipitals including notochord anomalies, neural tube defects, and errors in the development of the paraxial mesoderm (cells leading to development of the vertebral column, ribs, and exoccipitals)(Barnes, 1994:58). The latter includes errors in segmentation, differentiation, and developmental delay (Barnes, 1994: 58). Expression depends on the extent of the delay or error, producing a wide range of variation on bone.

2.1.1 BLASTEMAL STAGE

Following fertilization, the ovum undergoes cellular division leading to the formation of a mass of cells known as the morula (Heggeness, 1995:36). Cellular division continues and the morula becomes a hollow ball referred to as the blastocyst. The blastocyst is implanted into the endometrium after seven days. Eventually, some cells diverge to form the neural plate that later forms the neural tube, the precursor of the spinal cord and brain (Arey, 1965:405). Within the caudal end of the blastocyst, the embryonic disc forms. Initially, the disc consists of two layers (the ectoderm and endoderm) and soon develops a middle layer referred to as the mesoderm (Heggeness, 1995:36). As cell proliferation continues at the caudal end of the embryonic disc, cells begin to migrate upwards to form a thin tube of cells referred to as the notochord (Arey, 1965:406). The notochord is enclosed by a membranous sheath providing a framework for the development of the vertebral column, base of the skull, and the neural tube (Arey, 1965:405). These developments constitute the pre-embryonic period lasting three weeks.

The embryonic period begins when ectodermal cells, the layer overlying the notochord, enlarge and begin to form the neural folds. These folds eventually unite and form the neural tube (Barnes, 1994). Simultaneously, mesenchymal cells are drawn to each side of the notochord to form two columns known as the paraxial mesoderm. By day 21, these columns begin to differentiate into 43 pairs of block-like cells called somites (Arey, 1965:405). This process is usually complete by the

end of the fifth week of fetal development (Heggeness, 1995:36). The somites will eventually form the exoccipitals, the supraoccipital (the area between the superior nuchal line and the foramen magnum), and the vertebral column. Somite pairs develop simultaneously but independently, approaching each other at the same stage of development before uniting. Occasionally, additional or fewer somites are formed, leading to numerical variation in the vertebral column.

Once the somites have united, they begin to differentiate into three cell types: sclerotome which eventually becomes the vertebral column and ribs, myotome which becomes striated muscle, and the dermatome, the precursor of the dermis and subcutaneous tissue (Arey, 1965:405; Heggeness, 1995:36). The sclerotome segments around the notochord divide equally into cranial and caudal parts. By the third month, intervertebral discs are formed (Arey, 1965:405). The primordial vertebral bodies form once the caudal half of one sclerotome unites with the cranial half of the adjacent sclerotome (Bland, 1994:418). In other words, each vertebra consists of portions of two adjacent sclerotomes. Following segmentation, each vertebra begins to develop characteristic appearances of its corresponding region. Also during this stage, rib development begins from the costal processes growing from the primitive vertebral mass (Arey, 1965:409).

The prechordal cranial base then forms which is the precursor of the portions of the skull formed from cartilage e.g., the basioccipital and anterior portions of the occipital condyles; the portions of the temporals; the body, lesser wings, and roots of

the greater wings of the sphenoid; the ethmoid; and supraoccipital (Barnes, 1994:325). Neural plate cells begin to migrate to specific cranial regions where they are transformed into seven incomplete segments referred to as somitomeres. Somitomeres are precursors of the bones enclosing the brain. It is during the blastemal stage within which most developmental defects arise.

2.1.2 CARTILAGINOUS STAGE

By the sixth week, cartilage cells begin to replace the primitive vertebral column formed during the blastemal stage. Chondrification will not commence until the blastemal structures have reached their crucial size (Barnes, 1994:27). Vertebral centers of chondrification begin to appear by the sixth week in the highest vertebrae (Arey, 1965:406). Two centers of chondrification exist in each vertebral body while only one exists in each half of the vertebral arch. These four centers eventually coalesce into a solid, cartilaginous vertebra (Arey, 1965:407). By the third month the vertebral arches unite, enclosing the spinal cord. Failure of these centers to unite may either lead to underdevelopment (hypoplasia) or lack of development (aplasia) of vertebral structures. Rib development continues as the rib-tissue acquires a single center of chondrification during the seventh week. Later, a joint develops between the head of the rib and each thoracic vertebra (Barnes, 1994:28). Simultaneously, areas of the skull developing from a cartilage-based model (chondrocranium) begin to unite.

2.1.3 OSTEOGENIC STAGE

By the ninth week, ossification begins from a center within each lateral half of the vertebral arch (Arey, 1965:407). Vertebral centra appear to have a single center of ossification (Heggeness, 1995:39). In other words, a typical vertebra consists of one ossification center within the centrum and one on each side of the neural arch (Heggeness, 1995:39). The final union of these ossification centers is not complete until several years after birth. Also during the ninth week, a center of ossification appears in each rib near the site of their future angles (Arey, 1965:410). However, the anterior ends of the ribs remain cartilaginous, later becoming the costal cartilages (Barnes, 1994:30). The exoccipitals, including the occipital condyles begin to ossify by the ninth week (Arey, 1965:48).

With a brief explanation of the development of portions of the axial skeleton, one may have a better understanding of the development of defects within the areas of the vertebral column, ribs, and exoccipitals. In reviewing each stage of development (i.e., blastemal, chondrification, and ossification), for the most part, these defects occur in the blastemal stage when skeletal elements are most vulnerable to the effects of genetic and/or environmental influences. The range of susceptibility to disturbances during the process of development varies between groups, where every population has its own potential package of developmental defects (Barnes, 1994:321). Variation in the patterns of defect formation reflects the degree of genetic separation between groups resulting from cultural and geographic factors

over time (Barnes, 1994:321).

Jeffreys (1980:32) has simplified the classification of developmental abnormalities as those caused by adverse environmental factors, genetic abnormalities, and combinations of both (epigenetic). The majority of defects are caused by the latter, i.e. multiple genes and environmental influences (Barnes, 1994:10). Some individuals are more genetically prone to the effects of epigenetic or genetic upsets. Pedigree studies have revealed that several developmental defects follow familial lines of inheritance, suggesting a genetic origin (Bland, 1994:417). Environmental factors such as drugs and alcohol, irradiation, nutrition, maternal hormonal imbalances, variations in oxygen pressure, or infection may trigger the development of defects in genetically susceptible individuals (Bland, 1994:417; Barnes, 1994:10).

At a time of rapid change within the fetus, genetic or nongenetic factors can upset the process of normal skeletal development (Barnes, 1994:10). Only during this crucial period of vulnerability will a defect develop. Most defects relate to delays in the timing of events during morphogenesis. Any delay in skeletal development may lead to the presence of anomalous conditions resulting in hypoplasia (underdevelopment) or aplasia (lack of development) of skeletal parts (Barnes, 1994:11). For the following discussion, anomalies will be presented in the same order as they were by Barnes (1994).

2.2 ABNORMAL DEVELOPMENT

2.2.1 NOTOCHORD DEFECTS

The notochord is a flexible rodlike structure forming the main support for the development of portions of the skull and neural tube (Arey, 1965:405). Notochord defects arise within the blastemal/mesenchymal stage of skeletal development. The precursors of the vertebral bodies develop around the notochord. During normal development, the notochord regresses and disappears. However, in certain cases, defects in this region arise resulting from failure of the notochord to do so (Barnes, 1994:36). Anomalies of the notochord are characterized as coronal or sagittal clefts in or spikes on the vertebral bodies (mesenchymal diastematomyelia).

1. Coronal cleft centrum

When the anterior and posterior ossification centers of the centrum persist beyond the sixteenth week of fetal life, a coronal cleft develops (Epstein, 1976:185). Several vertebrae may be affected and are usually found in the thoracic and lumbar regions. Coronal clefts have not yet been recognized in the cervical region (Köhler and Zimmer, 1968:277). If normal growth should proceed, the condition will gradually disappear. In other words, coronal cleft centra are rarely recorded in adults (Epstein, 1976:186). Because of this, some have considered this condition as a mere temporary arrest in normal development and not as a true developmental defect (Köhler and Zimmer, 1968:268).

Coronal clefts are typically found in males, predominantly in premature babies and neonates (Ruge and Wiltse, 1977:242). Coronal cleft vertebrae are not infrequent. Using radiographs, Epstein (1976) recorded eighteen cases, all but one in newborns. Furthermore, Cuido and Newhauser (1956) recorded thirteen coronal cleft centra from the radiographs of 200 infants (from Epstein, 1976:186). In archaeological conditions, this anomaly remains difficult to recognize since fetal and newborn skeletal remains are rarely preserved.

2. Sagittal cleft centrum

A sagittal cleft results from failure of the notochord to recede leading to a lack of fusion between the lateral halves of a vertebral centrum (Epstein, 1976:188). This condition is characterized by a "pinching" of the centrum where the neural arches are not affected (Figure 2.1)(Barnes, 1994:36; Brasili et al., 2002:417). A sagittal cleft is also referred to as a "butterfly vertebra" because of its distinct wing-like appearance (Epstein, 1976:189). Several expressions of butterfly vertebra exist leading to the development of kyphosis or scoliosis in an individual (Brasili et al., 2002:417).

Sagittal cleft centra are rarely recorded and when found usually involve one vertebra (Köhler and Zimmer, 1968:276). However, Epstein (1976:189) suggests that multiple butterfly vertebrae are possible (e.g., Brasili et al., 2002).

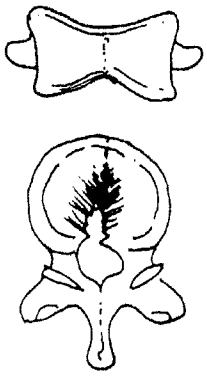

Figure 2.1 Sagittal cleft centrum resulting from failure of the notochord to regress (as adapted from Figure 3.1 of Barnes, 1994:37).

The affected vertebral segments are usually recorded within the thoracic and lumbar regions (Epstein, 1976:189; Barnes, 1994:37). Furthermore, sagittal cleft vertebrae are recorded more often in males than females (Brasili et al., 2002:417). Only a few reports of sagittal cleft centra have been recorded within the anthropological literature (e.g., Merbs and Wilson, 1962).

3. Mesenchymal diastematomyelia

Mesenchymal diastematomyelia is a rare condition characterized by the projection of a bony, cartilaginous, or fibrocartilaginous spur from the centrum (Figure 2.2)(Harris, 1959:48). As with coronal and sagittal clefts, mesenchymal diastematomyelia may be explained in terms of failure of the notochord to develop (Tsou et al., 1980:215). The spur prevents normal spinal cord development. With

full expression of this condition, the spinal column becomes bifurcated. As a result, the spinal canal is widened to accommodate the bifurcated cord. Most cases of mesenchymal diastematomyelia are found in the lumbar area (Harris, 1959:48). However, recent evidence suggests that this trait may also occur in the thoracic area (Barnes, 1994:39). This condition is sometimes found associated with spina bifida (Harris, 1959; Barnes, 1994:40).

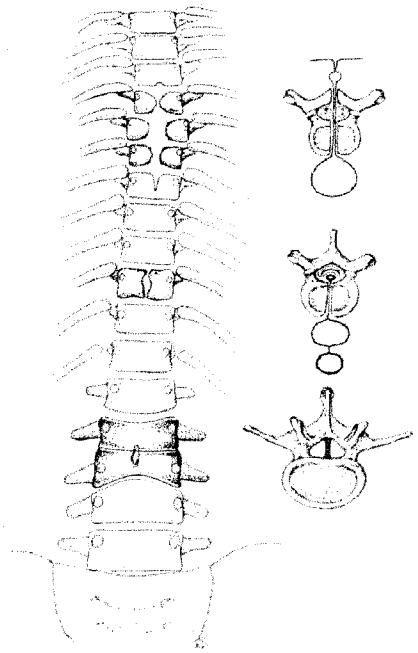

Figure 2.2 Various stages of mesenchymal diastematomyelia development (as adapted from Figure 2 of Tsou et al., 1980:215).

2.2.2 NEURAL TUBE DEFECTS

The neural tube is an embryonic structure formed by the folding of the neural plate. It eventually differentiates into the brain and spinal cord (Barnes, 1994:330).

There are several neural tube defects. However, attention is put on those affecting the regions of the exoccipitals and vertebral column including meningomyelocele, spinal meningocele with spina bifida cystica or occulta, and sacral agenesis. These conditions are known to have underlying genetic and nutritional causes (Bradtmiller, 1984:328).

Familial and genealogical data support a hypothesis of strong genetic influence on the incidence of neural tube defects (Dickel and Doran, 1989:326). Furthermore, deficiencies in dietary elements such as selenium, zinc, and folic acid have also been implicated in the development of these defects (Zimmerman and Lozzio, 1989:48). These elements are essential for cellular growth during development. A nutritional etiology may explain sporadic epidemics of neural tube defects in certain geographic regions (Barnes, 1994:41). Moreover, evidence suggests that certain populations are at greater risk of developing neural tube defects (Dickel and Doran, 1989:326).

1. Meningomyelocele

Meningomyelocele (myelomeningocele) results when the opening at either end of the embryonic neural canal, the posterior neuropore, fails to close (Barnes, 1994:44). As a result, portions of the spinal cord and nerve roots are moved outside the vertebral canal (Warkany, 1971:276). Meningomyelocele is generally accompanied by spina bifida cystica and usually involves several vertebrae. Spina

bifida is the failure of or lack of fusion between the neural arches of a vertebra (Warkany, 1971:274). Typically, the edges of this defect are raised or elevated (Figure 2.3). This anomaly is usually found in the lumbosacral region of the vertebral column (Warkany, 1971:282).

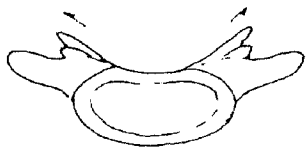

Figure 2.3 Meningomyelocele caused by failure of the posterior neuropore to close (as adapted from Figure 3.5f of Barnes, 1994:45).

Meningomyelocele is frequently found associated with other anomalies such as hydrocephalus and often presents a clinical condition of neurologic disability (Barnes, 1994:46). Various symptoms exist and most infants born with this defect die soon after birth. Because of its severity and resulting mortality, the condition may not be visible in the archaeological record resulting from poor preservation of infant skeletal material (Bradtmiller, 1984:328).

2. Spinal meningocele with spina bifida cystica

This is the least common form of spina bifida (Figure 2.4). The layers covering the spinal cord and brain (meninges) project through an opening in the

vertebral column (spina bifida cystica)(Barnes, 1994:47). Nerves are not usually terribly damaged and are functional. Therefore, an individual may present little disability when suffering from this condition and will likely survive into adulthood.

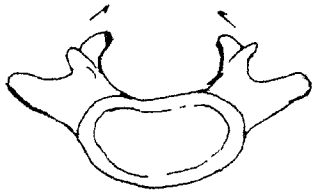

Figure 2.4 Spinal meningocele with spina bifida cystica resulting from failure of the neural tube to develop (as adapted from Figure 3.5e of Barnes, 1994:45).

This condition is less extreme compared to meningomyelocele (Warkany, 1971:283). However, making a differential diagnosis between the two conditions remains difficult (Dickel and Doran, 1989:326). Spina bifida has long been reported in the paleopathological literature (e.g., Dickel and Doran, 1989).

3. Spinal meningocele with spina bifida occulta

Spinal meningocele with spina bifida occulta is a common form of spina bifida (Figure 2.5). Between 0.5 and 10% of individuals may have the condition in varying degrees (Heggeness, 1995:46). For the majority of those affected, having spina bifida occulta is of no consequence at all.

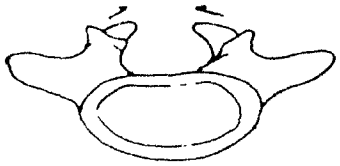

Figure 2.5 Spinal meningocele with spina bifida occulta caused by failure in development of the neural tube (as adapted from Figure 3.5d of Barnes, 1994:45).

However, for a few (about one in 1,000) there may be associated symptoms. With the occult condition, neither the meninges nor the spinal cord protrude from the canal as with meningomyelocele (Figure 2.3)(Heggeness, 1995:46). The presence of this defect may be detected by a thick tuft of hair or dimple on an individual's back (Bradtmiller, 1986:328).

A differential diagnosis between varieties of spina bifida is difficult. In the past, some researchers have mistaken one form for another or even with other defects (e.g., cleft neural arch). Regardless, the presence of spina bifida occulta has been frequently noted within the paleopathological literature. For example, Bradtmiller (1984) discusses two proto Arikara skeletal series (Sully and Larson sites of South Dakota) and compares their incidences of spina bifida occulta.

4. Sacral agenesis

Sacral agenesis, also known as caudal dysplasia, caudal regression syndrome, and rumplessness results from failure of the caudal portion of the neural tube to

develop (Barnes, 1994:50). It is a rare condition possessing varying degrees of expression including partial agenesis (hypoplasia) and complete agenesis (aplasia) (Figure 2.6).

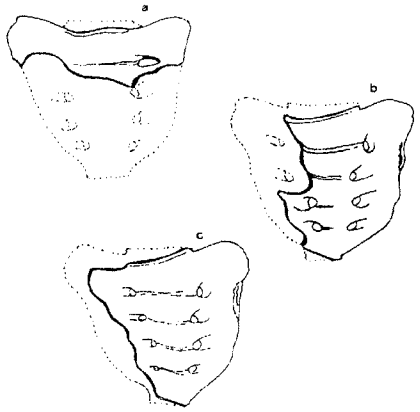

Figure 2.6 Varying degrees of sacral agenesis caused by failure of the caudal portion of the neural tube to develop (as adapted from Figure 3.7 of Barnes, 1994:51).

Males and females tend to be equally affected (Warkany, 1971:923). Congenital absence of the sacrum rarely occurs as a solitary defect and is usually part of a complex involving other abnormalities of the spine (Ruge and Wiltse, 1977:239). It is frequently associated with spina bifida cystica, "forked ribs," and Klippel-Feil syndrome (Warkany, 1971:923; Barnes, 1994:50).

In a study conducted by Warkany (1971), 50 patients born without a sacrum, were born to diabetic mothers. Furthermore, the role of genetic factors in the development of sacral agenesis was suggested through observations in laboratory mice. Warkany (1971:925), attributed sacral agenesis to a recessive mutant gene

occurring in a group of mice (Warkany, 1971:925). Additionally, similar malformations were genetically produced in rats using teratogenic agents such as trypan blue (dye), streptonigrin (highly toxic antibiotic), and others (Warkany, 1971:924). Teratogenic agents act in specific ways on developing cells and tissues to initiate abnormal development. Overall, the incidence of sacral agenesis may be misrepresented within the medical literature resulting from the use of differing terminology to refer to the condition, i.e., asomia and rumplessness (Warkany, 1971:923; Epstein, 1976:191). No specific case of agenesis of the sacrum could be found within the paleopathological literature (Barnes, 1994:51).

2.2.3 PARAXIAL MESODERM CONDITIONS

The paraxial mesoderm is the pair of primordial mesenchymal columns flanking each side of the notochord, straddling the development of the neural tube. This tissue eventually gives rise to the vertebral column, ribs, and exoccipitals (Barnes, 1994:331). As with neural tube defects, several genetic and environmental determinants have been proposed for alterations affecting the paraxial mesoderm. These defects are classed as those caused by temporal delays in segmentation, differentiation, and development (Barnes, 1994).

2.2.3.1 Segmentation Errors

1. <u>Asynchronous development of hemimetamere pairs</u>

During development, the paraxial mesoderm is subdivided into pairs of somites. These somites give rise to the vertebral column and exoccipitals (Barnes, 1994:59). Under normal conditions, somite pairs are in the same stage of development. However, if somite pairs are not at the same phase of development, the late side may shift down one segment and pair up with the next somite segment, resulting in a solitary hemivertebra sometimes referred to as a "wedge vertebra" (Figure 2.7)(Tsou et al., 1980:218). However, an isolated solitary hemivertebra is considered uncommon (Epstein, 1976:190). There are several varieties of hemimetamere pairs. A contralateral shift may occur where two hemivertebrae exist, one on each side of the midline, balancing each other (Figure 2.8)(Barnes, 1994:61).

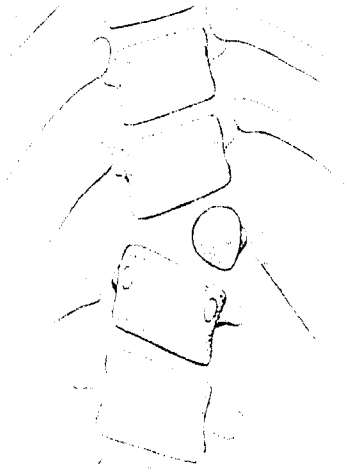

Figure 2.7 Solitary hemivertebra as a result of asynchronous development of hemimetameric pairs (as adapted from Figure 5 of Tsou et al., 1980:218).

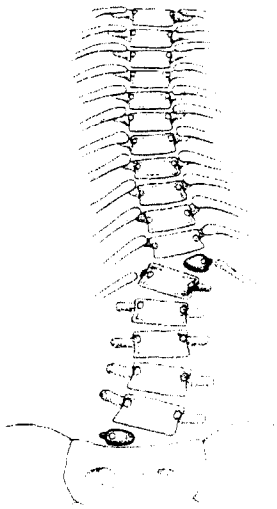

Figure 2.8 Contralateral hemivertebra (as adapted from Figure 6 of Tsou et al., 1980:219)

Conversely, two hemivertebrae may develop on one side of the midline, resulting in an unbalanced condition and the development of scoliosis (Figure 2.9). In all cases, hemivertebrae centra do not cross the midline of the vertebral column (Tsou et al., 1980:219).

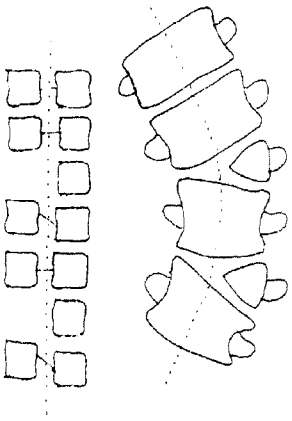

Figure 2.9 Unbalanced hemivertebra with centrum not crossing the midline (as adapted from Figure 3.9 of Barnes, 1994:61).

A hemivertebra may also develop resulting from failure of the appearance of an opposite ossification centre within the centrum. In other words, the remaining somite must develop without its partner. Here, the hemivertebral centrum crosses the midline (Tsou et al., 1980:214). Several variations exist depending on severity of the defect (i.e., hypoplasia/aplasia)(Figure 2.10). When multiple unilateral hypoplastic wedges occur, the segments frequently remain fused at the laminae. A postlateral bar may also develop and the apophyseal joints may be missing (Figure 2.10c,d)(Tsou et al., 1980:214).

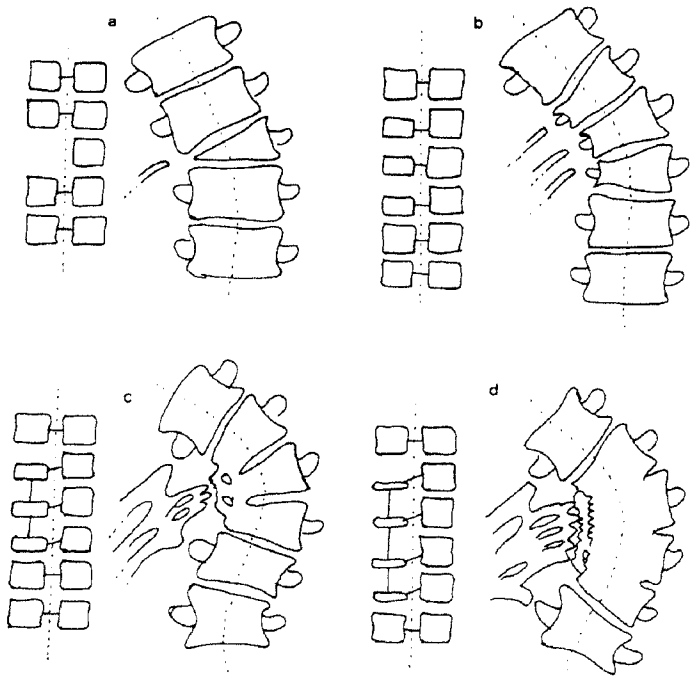

Figure 2.10 Variations of hemimetamere hypoplasia/aplasia: (a) solitary aplasia; (b) unilateral multiple hypoplasia; (c) unilateral multiple hypoplasia with a postlateral bar; and (d) an even more severe form of the later (as adapted from Figure 3.13 of Barnes, 1994:65).

The cause of both hemimetamere shifts and hypoplasia/aplasia remains obscure. Warkany (1971) suggests hereditary factors while others support the possibility of a chromosomal anomaly (Tsou et al., 1980:214). Little mention of hemimetameric shifts have been made in the paleopathological literature. However, during the analysis of 40 Maritime Archaic Indian skeletons (4400 - 3300 B.P.) from Port au Choix, Newfoundland, I discovered two cases of unilateral, solitary hemimetamere hypoplasia with an incidence rate of 5% (Pitre, 2003:47).

2. Failure of segmentation

As previously mentioned, the primordial vertebral body forms when the caudal half of one sclerotome unites with the cranial half of the adjacent sclerotome (Arey, 1965:405). Following this, a fissure appears as a precursor of the intervertebral disc. However, if this fissure fails to appear, a mass of tissue referred to as a block vertebra results (Epstein, 1976:179). This condition is also known as congenital synostosis (Gunderson et al., 1967:491). Severity depends on the extent of the delay. Typically, there is complete unity between the centra, whereas the neural arches may or may not be fused (Allbrook, 1955:495). Furthermore, fusion of adjacent ribs may sometimes occur. The cervical and lumbar segments are typically affected and several vertebrae may be involved.

Such fusion in the cervical vertebrae has become termed as "Klippel-Feil syndrome" (Bland, 1994:422). However, several other typologies have been added to the description of this syndrome. The condition was first described in 1912 by Maurice Klippel and André Feil in a patient exhibiting multiple cervical fusions, a low posterior hairline, and a short neck (Heggeness, 1995:42). Klippel-Feil syndrome is usually associated with hemivertebrae, cervical ribs, and occipitoatlantal fusion. Both genders are affected equally and this syndrome is usually painless (Bland, 1994:422). Recently, the syndrome has been used to describe any type of segmentation error involving the cervical vertebrae. Within this syndrome, three types of Klippel-Feil syndrome exist (Bland, 1994:422). Type I refers to the classic

case of fusion of several cervical and upper thoracic vertebrae; Type II is a fusion of two or three pairs of cervical vertebrae usually C2-C3, then C5-C6; and Type III is a combination of cervical and lower thoracic or lumbar fusion (da Silva, 1993:372). The Type II variety of Klippel-Feil syndrome is recorded most often (Brown et al., 1964:1257).

The etiology of this disorder appears to be epigenetic where both genetic and environmental factors have been implicated (Anderson, 1989:239). It has been suggested that different expressions of this trait follow different genetic paths, shown through familial tendencies favouring one type of expression over another. Both autosomal dominant and autosomal recessive models have been postulated, but transmission is far from understood (da-Silva, 1993:371). Gunderson et al. (1967) show that Type I and III variants of Klippel-Feil syndrome have an autosomal recessive mode of inheritance whereas Type II is an autosomal dominant trait. However, a more recent study by Bland (1994) points to an autosomal dominant mode of inheritance for the Type III variant of the Klippel-Feil complex.

No specific teratogen has been shown to produce cervical spine abnormalities in humans. However, thalidomide has produced increased numbers of vertebral fusions in the tails of rabbits (Gunderson et al., 1967:507). Recently, maternal alcoholism has been suggested as a significant factor in the production of the Klippel-Feil anomaly (Pizzutillo, 1989:262). A sex predilection has been recognized where more than 65% of cases of massive cervical fusion occur in females (e.g.,

Goodman and Gorlin, 1983; Merbs and Euler, 1985). However, others have found no sex-linkage (e.g., Jarcho and Levin, 1938; Wade, 1981; Bland, 1994).

Block vertebra(e) and Klippel-Feil syndrome have been mentioned within the paleopathological literature. For example, Allbrook (1955) described four cases of "non-pathological vertebral fusion" in East African skeletal material within the anthropological collection from the Department of Anatomy, Makerere College. These anomalies were found in "varying regions of the column" (Allbrook, 1955:495). Furthermore, Brown et al. (1967) analysed 1400 skeletons for the presence of both acquired and congenital fusions of the cervical spine. No designations were made between types of Klippel-Feil syndrome. An incidence rate of 0.71% was calculated where most of the blocks occurred among the second and third vertebrae (Type II Klippel-Feil syndrome). Lastly, I noted two cases of Type II Klippel-Feil syndrome (5%) during the analysis of the 40 Maritime Archaic Indian skeletons of Port au Choix, Newfoundland (4400 - 3300 B.P.)(Pitre, 2003).

3. *Irregular segmentation of ribs*

As stated above, the mesoderm undergoes a process of segmentation into pairs of somites. From this, the somites differentiate into the sclerotome from which the vertebrae develop (Sycamore, 1944:593). Ribs are derived from outgrowths of each of the developing vertebrae. Anomalies occur during the first step of division of the mesoderm into somites (Sycamore, 1944:593). Various expressions of rib

abnormalities exist and are generally found on the anterior ends (Martin, 1960). In Figures 2.11 A-H, examples of fusion, partial bridging with articulation, flaring, widening, bridging at the vertebral end, bifurcation, and spurring are presented.

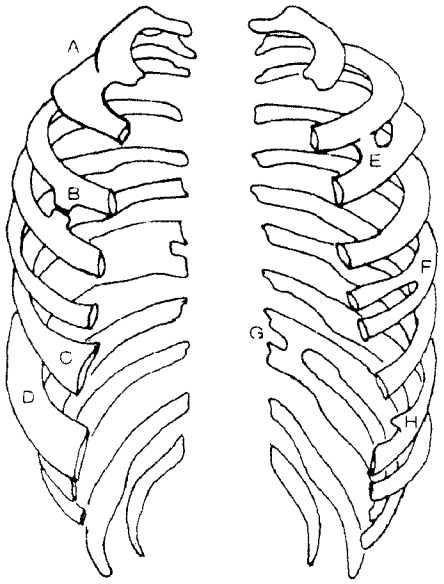

Figure 2.11. Various expressions of rib abnormalities caused by failure in segmentation (A) fusion; (B) partial bridging with articulation; (C) flaring; (D) wide; (E) bridging (G) at vertebral end; (F) bifurcation; (H) spur (as adapted from Figure 3.18 of Barnes, 1994:74).

Several examples of rib abnormalities have been mentioned in the anatomical literature. For example, Martin (1960) observed a high incidence (8.4%) of rib abnormalities from chest x-rays in a recent Samoan population. A 2:1 distribution between males (11%) and females (5.8%) was suggestive of a sex-influenced genetic pattern of inheritance. Additionally, Martin (1960) suggested an environmentally

induced endogamy as a secondary factor to explain the high incidence of rib defects found in the Samoans. Furthermore, Warkany (1971) observed a variety of congenital deformities of the ribs in animals born to mothers experiencing nutritional deficiencies during their pregnancy. This suggests that vitamin deficiencies could potentially cause human ribs to acquire abnormal shapes.

4. Neural arch joint failure of segmentation

Apophyseal joints are the bony outgrowths between adjacent vertebrae that form an articulation (Barnes, 1994:76). Failure in segmentation between apophyseal joints is caused by injury to the primitive mesenchymal tissue (Tsou et al., 1980:224). This tissue is then ossified and the intended joint does not develop, thereby limiting movement (Figure 2.12)(Tsou et al., 1980:224). Furthermore, failure in segmentation between costovertebral joints may occur when the costal joint fails to develop and the rib becomes an abnormal extension of the vertebra (Figure 2.13)(Tsou et al., 1980:76). No cases of these types of defects could be found within the paleopathological literature.

5. Numerical errors of segmentation

Given normal circumstances, a typical spinal column consists of seven cervical, twelve thoracic, five each lumbar and sacral, and four coccygeal vertebrae (Abrahams et al., 1998).

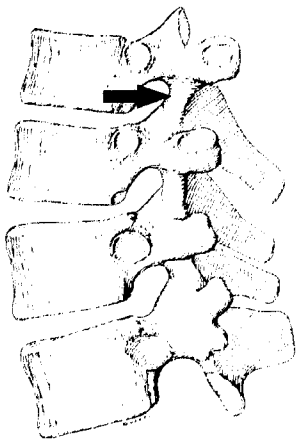

Figure 2.12 Cohesion of apophyseal facets (as adapted from Figure 13 of Tsou et al., 1980:224).

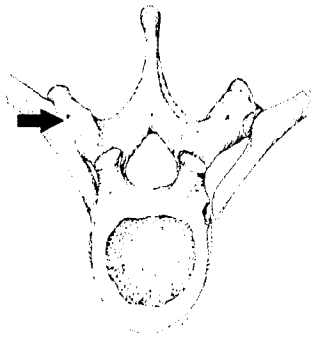

Figure 2.13 Failure of the costovertebral joints to develop (as adapted from Figure 14 of Tsou et al., 1980:225).

A vertebral column not consisting of the modal number of vertebral segments (33) has experienced a numerical error of segmentation. Numerical variation in the number of vertebrae relates to an abnormal number of somites derived during the subdivision of the columns of the paraxial mesoderm (Barnes, 1994:78). Supernumerary segments are generally noted in bordering regions, taking on characteristics of the surrounding vertebrae. A reduction in vertebral segments is generally rare, whereas supernumerary segments have been described within the literature (Allbrook, 1955; Bornstein and Peterson, 1966). In an archaeological context, poor preservation must first be ruled out before an accurate assessment can be made (Allbrook, 1955:491).

Shore (1930) believed that there is a tendency toward an increase in number

of vertebrae in several orders of Mammalia, while in primates and humans, a tendency toward reduction appears to occur (Shore, 1930:234). On the other hand, Bornstein and Peterson (1966) suggested that number of vertebrae varies from population to population and that there is a tendency in all groups toward an increase in number in males and a decrease in number in females. However, they offer little explanation as to why this trend may exist. Therefore, Shore (1930) and Bornstein and Peterson (1966) advocate an "evolutionary" explanation for the emergence of numerical variation within the vertebral column.

Numerical variation of the vertebral column has been recorded within the paleopathological literature. For example, Barclay-Smith (1911) described a case of an eighth cervical vertebra possessing a small rib. This defect was found in a young woman discovered from the Sakkara site in Egypt dating from the fourth dynasty (Barclay-Smith, 1911:143). Additional vertebrae at the cervicothoracic border are considered rare (Barnes, 1994:78). Furthermore, de Beer Kaufman (1974) examined the recent skeletons of several southern African blacks from the Raymond A. Dart collection. Here, the total incidence of numerical variation was 19% in males and 12.1% in females. A predilection was found for this trait in males.

2.2.3.2 Failures in Differentiation

Border shifts result in variation vertebral characteristics and in some cases, variation in the number of vertebrae found in each region. Shifts can occur in two

directions: cranial and caudal (Merbs, 1974:12). With a cranial shift, the border between two vertebrae (e.g., between cervical and thoracic) moves upwards and in this case, the last cervical vertebra develops thoracic-like characteristics. With caudal shifting the reverse is true. The border found between two regions moves downwards. Using the previous example, the first thoracic vertebra would develop cervical-like characteristics (Barnes, 1994:80).

Characteristics will vary depending on the extent of the shift. The neural arch is primarily affected as well as the transverse processes and apophyseal joints, while the body is usually spared. Shifts are typically recorded at the occipitocervical and lumbosacral borders. As a result, these borders are considered less stable. However, shifting is not uncommon at more stable borders (i.e., cervicothoracic, thoracolumbar, and sacrocaudal). The cause of these shifts is uncertain (Merbs, 1974:12). However, delay in the formation of the intervertebral disc space between adjacent vertebrae may likely be a trigger (Barnes, 1994:80).

Within the literature it has been suggested that there is a genetic component regarding shifting tendencies at specific borders. Cranial shifts are recorded more often in females than males (Barnes, 1994:80). Furthermore, vertebral border shifting patterns have been shown to vary from population to population (Shore 1930; Stewart, 1932; Allbrook 1955). Even more specifically, Kühne (1932) states that there is a tendency for shifting in the same direction in genetically-related individuals (from Allbrook, 1955:499). Kühne also believed that caudal shifts were

controlled by a recessive gene and cranial shifts by a Mendelian dominant gene (from Allbrook, 1955:499). However, shifting has been observed in different directions within the same individual (Shore, 1930; Searl, 1954; Allbrook, 1955; Bornstein and Peterson, 1966; Schmorl and Junghanns, 1971; and Merbs, 1974). Therefore, it seems likely that an array of factors may influence direction of shift in an individual.

Recent evidence indicates that a set of regulator genes referred to as HOX genes are involved in the irregular differentiation of the vertebral column (Saegusa et al., 1996; Innis, 1997). HOX genes are thought to determine a future somites' form, where problems in the regulation of these genes can lead to one vertebra taking on the appearance of another (shifting)(Saegusa et al., 1996). An individual can be born without the necessary cells to carry out the chain of events during differentiation, or environmental disturbances can disrupt the normal pathway of development, leading to a shift in vertebral appearance (Martínez-Frías, 1994).

1. Occipitocervical border

a) cranial shift

A complete shift at the occipitocervical border results in the development of an occipital vertebra (Barnes, 1994). An occipital vertebra appears as an extension of the rim of the foramen magnum (Figure 2.14). This condition has several more minor manifestations including precondylar tubercles, bipartite condylar facets, transverse basilar clefts, bipartite hypoglossal canals, and odontoid displacements

(Lombardi, 1961:260). Most expressions of the occipital vertebra present no clinical significance (Barnes, 1994:84).

Figure 2.14 Occipital vertebra (as adapted from Figure 3.22 of Barnes, 1994:83).

Precondylar tubercles are found on the inferior rim of the foramen magnum (Figure 2.15)(Hauser and De Stefano, 1989:135). These defects vary in size and present no clinical significance. Their manifestation is suggested as being genetically controlled. However, they continue to yield heritability estimates of zero (Hauser and De Stefano, 1989:135). Furthermore, no consistent age or sexual predilections concerning incidence rates have been reported (Hauser and De Stefano, 1989:136).

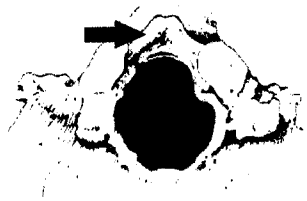

Figure 2.15 Precondylar tubercle on the anterior rim of the foramen magnum (as adapted from Figure of 1 of Peyton and Peterson, 1942:133)

The size and position of the occipital condyles may also show great variation. At birth, the occipital condyles are found as part of both the exoccipitals and basioccipitals. If the ossification of these two centres does not proceed by the second embryonic month, pinching of the occipital condyle occurs (Figure 2.16)(O'Rahilly et al., 1983). Within the literature, there exists no sex predilection for this trait (Hauser and De Stefano, 1989:118).

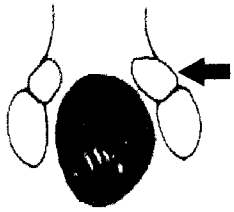

Figure 2.16 Bipartite occipital condylar facets as evidence of mild cranial shifting at the occipitocervical border (as adapted from Figure 3.22 of Barnes, 1994:83).

A transverse basilar cleft is a rare condition, constituting another form of mild cranial shift at the occipitocervical border (Figure 2.17). These clefts can be complete but most remain incomplete (Lombardi, 1961:266).

Bipartite hypoglossal canals are another minor expression of cranial shifting at the occipitocervical border. The various expressions of this trait reflect the original segmentation of the occipital sclerotomes (Type I- small spicule; Type II-

two spicules; Type III- asymmetrical bridge; Type IV- symmetrical bridge (Barnes, 1994:82).

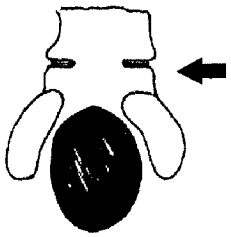

Figure 2.17 Transverse basilar cleft resulting from minor cranial shift at the occipitocervical border (as adapted from Figure 3.22 of Barnes, 1994:83).

Often, this trait is already established well before birth, suggesting the existence of a genetic factor in the expression of this bridging (Hauser and De Stefano, 1989:122).

Malformation of the odontoid process of the second cervical vertebra is also considered result of cranial shifting at the occipitocervical border (Bland, 1994:410). Defects of the odontoid are more common in individuals with Down's syndrome, Klippel-Feil syndrome, and other skeletal malformations. Several odontoid displacements exist including os odontoideum; ossiculum terminale; and various extremes of agenesis or hypoplasia of portions of the odontoid.

Os odontoideum (Figure 2.18A) occurs when the dens develops separately from the body of the axis. This is the most common defect affecting the odontoid process and its etiology is uncertain. Whitecloud III and Brinker (1992) believe that os odontoideum may arise because of trauma or infection. Therefore, there are

doubts concerning the developmental etiology of this condition (Heggeness, 1995:42).

Ossiculum terminale (odontoid hypoplasia)(Figure 2.18B) occurs when the apical tip of the odontoid process remains separated, resulting in a short and rudimentary-looking odontoid. The apical tip of the odontoid process usually unites with the dens by six to nine years. However, if this process is not complete, it may present as a shortened and blunt dens (Epstein, 1976:161)

Furthermore, agenesis of the dens or the apical segment occurs as result of a cranial shift at the occipitocervical border. In severe cases, complete agenesis of the odontoid process may occur (Figure 2.18C)(Barnes, 1994:86-87). The frequency of anomalies of the odontoid process is uncertain.

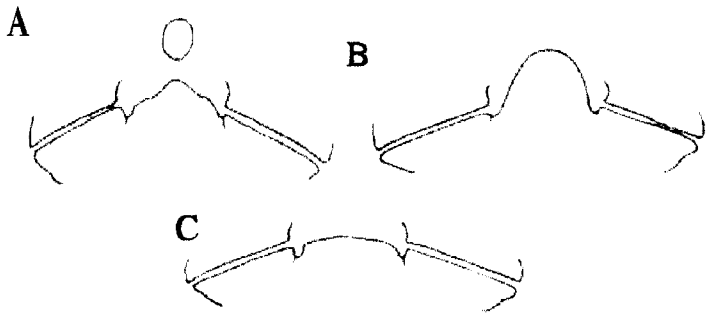

Figure 2.18 Varieties of odontoid displacements including (A) os odontoideum (B) ossiculum terminale and (C) agenesis of the dens (as adapted from Figure 3.6 of Jeffereys, 1980:35).

The paleopathological literature concerning cranial shifting at the

occipitocervical border is generally lacking. Some mention of the complete expression (occipital vertebra) does occur. However, little mention of minor expressions is made. Most of the information concerning these anomalies originates from the radiographic literature. However, during the examination of 40 Maritime Archaic Indian skeletons from Port au Choix, Newfoundland (4400 - 3300 B.P.), several more minor manifestations of shift were recorded at this border (Pitre, 2003). For example, a rare case of transverse cleft was noted on the basilar portion of the occipital bone of a 22-30 year-old female (NP 49A). Furthermore, several varieties of bipartite hypoglossal canals were noted on the skeletons of several of the Maritime Archaic Indians with an incidence rate of 33% (13/40)(Pitre, 2003).

b) caudal shift

At the occipitocervical border, a complete caudal shift results in what is referred to as occipitalization of the atlas. This condition has been widely recorded within both the radiographic and paleopathological literature. Several degrees of fusion may exist involving the anterior and/or posterior arches of the atlas (Figure 2.19)(Shapiro and Robinson, 1976:283). Occipitalization of the atlas is frequently associated with fusion of C2 and C3 (McRae and Barnum, 1953; Merbs and Euler, 1985). The development of this condition is related to failure of differentiation between sclerotomes and the majority of patients exhibiting this trait almost always present clinical symptoms (Bland, 1994:420).

Figure 2.19 Occipitalization of the atlas (as adapted from Figure 1 of Peyton and Peterson, 1942:133).

Besides the complete expression of shifting at this border, several milder expressions exist including paracondylar processes; hypoplasia of condylar facets; epitransverse processes; and precondylar facets (Barnes, 1994:130).

Paracondylar processes (also referred to as paramastoid and paraoccipital processes) occur as bony protrusions found between an occipital condyle and the mastoid process of the temporal bone (Epstein, 1976:157)(Figure 2.20). The early onset of this trait suggests a genetic link. Furthermore, paracondylar processes show a high incidence in females in most studies (Hauser and De Stefano, 1989:130).

Figure 2.20 Paracondylar process (as adapted from Figure 3.22 of Barnes, 1994:83).

Condylar hypoplasia (Figure 2.21) occurs in isolation or in association with

occipitalization of the atlas (Shapiro and Robinson, 1976:285). There are several varieties of this defect where the occipital condyles appear smaller than usual. Condylar hypoplasia results from failure of the exoccipital portion of the condyles to develop (Barnes, 1994:89).

Occasionally, a thin strut of bone is noted on the transverse process of the atlas, pointing toward the occipital condyles (Figure 2.22). This spicule of bone is referred to as an "epitransverse process"(Shapiro and Robinson, 1976:284). These processes can be positioned unilaterally or bilaterally and a variety of forms exist (Epstein, 1976:158).

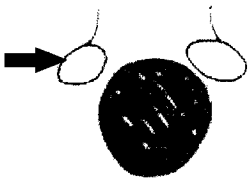

Figure 2.21 Hypoplasia of the occipital condyles resulting from caudal shift at the occipitocervical border (as adapted from Figure 3.22 of Barnes, 1994:83.

Figure 2.22 Epitransverse process resulting from mild expression of caudal shift at the occipitocervical border (as adapted from Figure 3.22 of Barnes, 1994:83).

Barnes (1994) has also considered atlas bridging as a mild form of caudal shifting at the occipitocervical border. However, Hauser and De Stefano (1989) consider it as a manifestation of an occipital vertebra (i.e., cranial shifting as opposed

to caudal shifting). Following Barnes (1994), atlas bridging will be considered as a form of caudal shifting within this research. Various expressions of both lateral and posterior arch bridges have been recorded (Figure 2.23)(Hauser and De Stefano, 1989:111). Furthermore, asymmetrical cases have been recorded more frequently compared to symmetrical occurrences. Atlas bridging is considered as a "very valuable" genetic marker in skeletal studies (Selby et al., 1955:140). It is thought to be inherited as a Mendelian dominant trait.

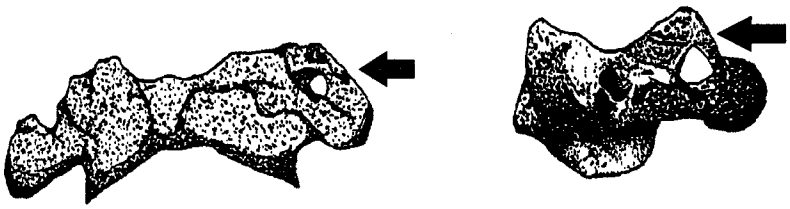

Figure 2.23 Drawings of (left) complete lateral arch and (right) posterior arch bridging (as adapted from Figure 17 of Hauser and De Stefano, 1989:111).

Finally, precondylar facets (also known as "the third condyle") are located between the occipital condyles on the basilar portion of the occipital bone (Allen, 1881:60)(Figure 2.24). This malformation develops during the blastemal stage of development during the period when the odontoid is descending to a position below the foramen magnum (Allen, 1881:60). A caudal shift at this border may prevent the odontoid process' normal descent, causing it to protrude into the foramen magnum, leading to the development of this "third condyle" (Epstein, 1976:157).

Figure 2.24 Precondylar facet as a mild expression of caudal shift at the occipitocervical border (as adapted from Figure 3.22 of Barnes, 1994:83).

Within the paleopathological literature, several cases of complete and mild expressions of caudal shift at the occipitocervical border have been recorded. For example, Gregg and Steele (1969) analysed a series of 984 Indian burials from North and South Dakota. A large part of the sample came from two burial grounds: the Leavenworth and the Arikara Sully Sites where the temporal span of these sites is unclear. They recorded the presence of occipitalization of the atlas and paracondylar processes at an incidence rate of 0.3%. Similarly, Williams (1982) recorded a paracondylar process measuring more than 20 millimetres in a Plains Woodland Burial in north-central Grand Forks County, North Dakota. Finally, during the examination of 40 Maritime Archaic Indian skeletons, I noted the presence of several cases of bridging of the arch of the atlas in seven males (7/40 = 18%)(Pitre, 2003). Because this trait is known to be a valuable genetic marker, its high incidence on male skeletons within this collection was used to suggest that they may have been related, supporting previous research conducted by Kennedy (1981).

c) basilar impression

Basilar impression, also referred to as basilar invagination, is a condition where the rim of the foramen magnum appears to have been pushed upwards (Bland, 1994:407). This malformation should not be confused with platybasia which is an increase in the basal angle of the skull (Raynor, 1989:227). Most often mention of this condition is found within medical and radiologic sources. On living subjects the presence of this condition can be measured by drawing a series of lines on radiographs (Bland, 1994:419). However, on dry bone, this trait appears as any indentation in the base of the skull. Basilar impression is generally associated with other anomalies such as occipitalization of the atlas (Bland, 1994:419). Trauma, rickets, and Pagets' osteitis have been implicated as agents of causation for this malformation of the foramen magnum (Peyton and Peterson, 1942:132). Mention of basilar impression in the literature is sparse. However, Gregg and Gregg (1987) noted a case basilar impression on a Sioux male skull. The etiology of this specific case is unknown. Definitive research is required to determine the developmental cause(s) of basilar impression and methods to recognize its presence on dry bone.

2. Cervicothoracic border

a) cranial shift

At the cervicothoracic border, a complete cranial shift causes the costal processes of the seventh cervical vertebra to persist, forming a "cervical rib" (Bland,

1994:407)(Figure 2.25). A cervical rib may possess a head, neck, and body similar to the thoracic ribs below (Todd, 1987; 1912). Evidence for cervical ribs has been recorded on every cervical vertebra except the atlas (O'Rahilly et al., 1983:193). Honeij (1920) noted that cervical ribs were recorded more often in females; however, opinions vary.

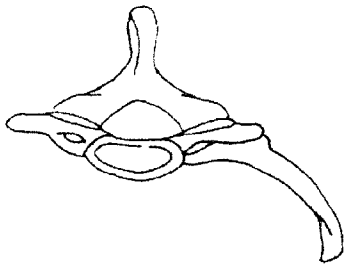

Figure 2.25 Complete expression of cranial shifting at the cervicothoracic border: cervical rib (as adapted from Figure 3.31 of Barnes, 1994:103).

Between 50 and 75% of individuals developing cervical ribs will present no clinical symptoms (Barnes, 1994:101). These accessory ribs are considered "counter evolutionary" since there is generally thought to be an overall trend toward a reduction in total number of ribs (Black and Scheuer, 1997:2). Still today, evidence as to the cause and influencing factors in the development of cervical ribs is sparse and some researches believe them to result from an interference of surrounding tissues. Some individuals may not experience a complete shift at this border leading to the development of a cervical rib. A mild cranial shift at the cervicothoracic border results in the attachment of the second thoracic rib to the lateral edge of the

manubrium instead of the manubriosternal junction (Gladstone and Wakeley, 1932).

Cases of cervical ribs have been reported within the paleopathological literature. For example, Black and Scheuer (1997) described a case of a cervical rib on the seventh cervical vertebra of a nineteenth-century 42 year-old female skeleton from the St Bride's skeletal collection, London. The rib possessed a well-defined head, tubercle, groove for the subclavian artery, and a scalene tubercle (Black and Scheuer, 1997:6). Furthermore, during the analysis of the Maritime Archaic Indian remains (4400 - 3300 B.P.) from Port au Choix, Newfoundland, Canada, I discovered a mild case of a cervical rib (Pitre, 2003:21). The skeleton of a 45-70 year-old male (NP 08A) presented a bony tubercle on the right costal process of C7.

b) caudal shift

A caudal shift at the cervicothoracic border causes the first thoracic rib to become underdeveloped and rudimentary in size (Barnes, 1994:102). The border between C7 and T1 moves down leaving T1 to develop in the "cervical area." Often, the transverse processes of the first thoracic vertebra also exhibit cervical-like transverse foramina (Barnes, 1994:102). Rudimentary first thoracic ribs are generally located unilaterally and have a higher incidence in males compared to females (Barnes, 1994:104). Most cases of rudimentary thoracic ribs are symptomatic producing irritation and/or pressure on the surrounding tissues. With mild caudal shifting at the cervicothoracic border, the second thoracic rib attaches to

the mesosternum instead of the manubriosternal joint (Barnes, 1994:104).

Cases of rudimentary first thoracic ribs have been noted within the anatomical literature. For example, Dow (1925) carried out a literature review and discovered six cases of rudimentary first thoracic ribs. Furthermore, Gladstone and Wakeley (1932) mentioned rudimentary first thoracic ribs within their review of cervical rib clinical and etiological standpoints. Again, the cause of this malformation is generally not well understood.

3. *Thoracolumbar border*

a) cranial shift

At the thoracolumbar border, a complete expression of cranial shifting results in a reduction in size of the twelfth thoracic ribs. Even more extreme, the twelfth thoracic ribs may be absent (Barnes, 1994:104). In this case, the border between T12 and L1 moves upwards, pushing T12 into the lumbar region during development. Therefore, the twelfth thoracic vertebra develops "lumbar-like" characteristics e.g., underdevelopment or lack of development of ribs. A mild shift results in the development of transitional inferior articular facets on the eleventh thoracic vertebra instead of the twelfth (Barnes, 1994:104). In other words, the transitional facets are moved up to the next thoracic vertebra since T12 becomes more "lumbar-like." In Merbs' (1974) study, these characteristics were recorded at an incidence rate of 2.8% in the Sadlermuit and 7.1% in the Northwest Coast

Indians.

b) caudal shift

A complete shift at the thoracolumbar border results in what is known as a lumbar rib. The border between T12 and L1 moves downwards, pushing L1 into the thoracic region during development. Therefore, L1 develops a rib that is characteristically broad with a rounded, blunt, or oval tip (Barnes, 1994:132). Lumbar ribs vary in length and are more often noted in females than males (Warkany, 1971:933). Generally, lumbar ribs are considered less common than cervical ribs. With mild expression of caudal shifting at the thoracolumbar border, transitional inferior articular facets develop on L1 instead of T12.

Within the anatomical literature, Steiner (1943) reported lumbar ribs in five males and twelve females from x-rays. Furthermore, Merbs (1974) recorded caudal shifting at the thoracolumbar border in 40% of the Sadlermiut vertebrae and 25.7% of the Northwest Coast Indian columns (i.e., Haida, Kwakiutl, Nootka). More Recently, Ogilvie et al. (1997) recorded lumbar anomalies in the Shanidar 3 Neandertal, a 35-50 year-old male from Iraq.

4. *Lumbosacral border*

a) cranial shift

The lumbosacral border is often considered the most active regarding

imperfect segmentation and shifting (Barnes, 1994:108). A complete shift at the lumbosacral border results in sacralization of the fifth lumbar vertebra (Figure 2.26). Here, the border between L5 and S1 moves upwards pushing L5 to develop within the sacral region. One or both sides may become sacralized (Harris, 1959:43).

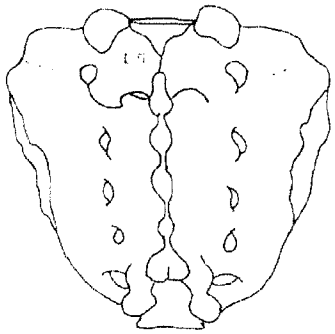

Figure 2.26 Sacralization of L5 due to cranial shift at the lumbosacral border (as adapted from Figure 3.36 of Barnes, 1994:112).

The transverse processes of L5 may articulate with the sacrum and/or the ilium (Allbrook, 1955:495). A clinical significance arises only in circumstances where incomplete sacralization occurs. Other minor expressions of assimilation at this border lead to the development of ala-like transverse processes on L5 (Barnes, 1994:132).

Cases of sacralization have been reported within the paleopathological literature. For example, Allbrook (1955) recorded unilateral and bilateral instances of this malformation. In 200 vertebral columns, total incidence was calculated to be

11%. Within this study, evidence of sacralization usually occurred bilaterally. However, when it did present as a unilateral defect, it was always found on the left (Allbrook, 1955:495). Furthermore, among the miscellaneous bones of lot FS-4158 of the Gran Quivira site, New Mexico (1300-1670 A.D.), Reed (1981) reported a sacrum with the last lumbar incompletely sacralized on the right.

b) caudal shift

With a caudal shift, the first sacral segment attempts to "break free" from the sacrum (Shore, 1930:215). This condition is characterized by the development of lumbar-like characteristics by S1 (Figure 2.27).

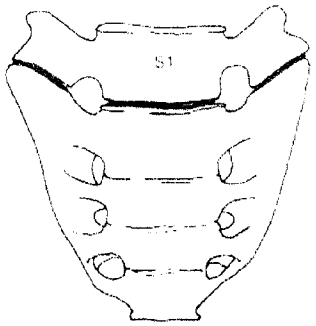

Figure 2.27 Lumbarization of the 1st sacral vertebra, evidence of caudal shifting at the lumbosacral border (as adapted from Figure 3.36 of Barnes, 1994:112).

This process may occur completely or incompletely where various expressions exist. This developmental defect is known as "lumbarization" of S1. A mild caudal shift at

the lumbosacral border results in the development of an anterior cleft between the first and second sacral segments and the presence of rudimentary apophyseal facets between the same two segments (Shore, 1930:215).

Cases of caudal shift have been reported within the paleopathological literature. For example, Usher and Christensen (2000) recorded lumbarization of S1 on the skeleton of a Danish woman from the 12th century A.D. The defect was incomplete with clear shifting on the right side whereas the left side was unaffected. Furthermore, during the analysis of the 40 Maritime Archaic Indians from Port au Choix, Newfoundland (4400 - 3300 B.P.), I discovered seven examples of caudal shift at this vertebral border (7/40 = 18%). The expression was in the form of an anterior cleft between S1 and S2 coupled with rudimentary apophyseal facets between S1 and S2 (Pitre, 2003). Of the seven sacra, five were those of males and two were females.

5. Sacrocaudal border

a) cranial shift

A cranial shift at the sacrocaudal border results in the complete or incomplete separation of the last sacral segment from the sacrum. The last sacral segment develops coccygeal-like characteristics. At the sacrocaudal border, an incomplete shift is more common than the complete expression (Barnes, 1994:114). Shifting in a cranial direction at the sacrocaudal border is rarely mentioned within the literature.

b) caudal shift

As the border between the sacral and coccygeal segments shifts downwards, the first coccygeal vertebra becomes sacralized. This form of shifting occurs more often than cranial shifting (Barnes, 1994:114). Mention of assimilation of the first coccygeal segment is also rare within the paleopathological literature. However, Reed (1981) recorded twelve cases (four males, eight females) of sacralization of the first segment of the coccyx in the Las Humanas, Gran Quivira skeletal collection from New Mexico (1300-1670 A.D.). Whether a sex predilection exists for this trait remains unknown.

2.2.3.3 Developmental Delay

Delay in the development of vertebral elements typically occurs during the blastemal stage of morphogenesis (Barnes, 1994:117). Failure of a structure to reach its critical size within this stage results in the chondrification and subsequent ossification of parts reduced in size (hypoplasia). Furthermore, the failure of the structure to develop (aplasia) can occur (Barnes, 1994:117). Developmental delay can occur in any of the vertebral structures (e.g., laminae, pedicles, spinous processes, centra etc.).

1. <u>Hypoplasia - aplasia of the elements of the neural arch</u>

During the sixth week of blastemal development, chondrification centers

appear in the middle of each neural arch (Barnes, 1994:117). Chondrification then proceeds into the pedicles, centra, laminae, articular, transverse and spinous processes. By the ninth week of development, ossification centers appear where the halves of the arch remain separate from each other and the centrum until after birth (Arey, 1965:407). Any minor delay in the union of the two arches may result in bifurcation (narrow separation), whereas a major delay results in a cleft (wide separation). Furthermore, cases of hypoplasia of the neural arch without the presence of clefting or bifurcation have been recorded. For example, aplasia of the pedicles or laminae or other elements of the neural arch may occur (Epstein, 1976:172). Additionally, the articular facets of the apophyseal joint or the spinous and transverse processes may be rudimentary or absent (Barnes, 1994).

Cleft neural arch is commonly referred to as spina bifida. However, the two are in fact caused by two different processes. Spina bifida is a neural tube defect whereas cleft neural arch is considered as a failure or lack in development of the neural arch (Barnes, 1994:119). Differential diagnosis between the two conditions remains difficult in skeletal populations. However, with neural tube defects, the edges of the neural arch are pushed outward, whereas the edges of a cleft are not as raised (Barnes, 1994:49). Typically, cleft neural arch appears in bordering regions where the lumbosacral junction has shown a high incidence of this trait (Barnes, 1994:119).

Cases of aplasia and hypoplasia of the elements of the neural arch have been

recorded within skeletal collections. For example, Reed (1981) analysed the skeletal remains of lot FS-4158 of the Gran Quivira site, New Mexico (1300-1670 A.D.) and discovered a bifid spinous process on the fifth lumbar of skeleton number 169. Recently, Usher and Christensen (2000) recorded a missing right pedicle the twelfth thoracic vertebra of a young Danish woman from the 12th century A.D. Furthermore, during the examination of the 40 skeletons from the Maritime Archaic Indian collection from Port au Choix, Newfoundland (4400 - 3300 B.P.), I noted a lack of transverse processes on the first lumbar vertebra of a 25-50 year-old male (NP 37A)(Pitre, 2003).

2. *Hypoplasia - aplasia of the centrum*

Hypoplasia or aplasia of the centrum can take place within the blastemal stage of development. A vertebral body chondrifies through a pair of centers appearing by the sixth week of development (Heggeness, 1995:39). Ossification of a vertebral body begins by the ninth week. Any interference in the development of the centra within the blastemal stage may produce hypoplastic or aplastic conditions. The exact cause of centrum aplasia is unknown. Tsou et al. (1980) theorize that a congenital absence of vascularization or local disruptions may lead to problems in the development of the centrum. Anterior and/or posterior hypoplasia of the centrum has been noted, leading to the ossification of an abnormally small vertebral body (Barnes, 1994:126). Complete aplasia of the centrum is rare and leads to

kyphosis. The presence of these anomalies is rarely recorded within the literature.

Therefore, during development, the skeleton is most vulnerable to the effects of genetic or epigenetic influences. Timing is crucial. Any temporal deviation in the normal sequence may lead to the development of an anomalous condition. Abnormal development in the regions of the vertebral column, ribs, and exoccipitals may result in notochord defects, neural tube anomalies, or errors in the development of the paraxial mesoderm. Several of these defects have and continue to be recorded in skeletal material and in recent individuals through the study of radiographs.

CHAPTER 3: HISTORICAL BACKGROUND AND OSTEOLOGICAL ANALYSES

3.1 QUAKER BURIAL GROUND

The religious sect "Society of Friends" more commonly known as Quakers is religious group of Protestant denomination, founded by George Fox (1624-1691) in the mid-17th century in England (Stock, 1998:129). This society is one of many groups that broke away from the Christian church during a time of religious, social, and political upheaval in England and to an even greater extent, Europe. The Quaker name is said to have originated during an incident involving the sect's founder George Fox (Stock, 1996:10). While appearing in court in 1650, Fox declared that the justices and those around him should "tremble at the name of the Lord." Justice Bennett of Derby then scornfully called Fox and the other members of the society "Quakers" (Stock, 1996:11). It was not until 1689 that Quakerism became tolerated (Gillman, 1993:3). Today, there are some 240,000 members worldwide (Gillman, 1993:1).

Members of the Society of Friends live by *The Book of Discipline*. Its doctrines explain the rejection of formal sacraments, religious symbols, and violence (Stock, 1998:129). Within the Society of Friends there is equality between the sexes and elders are treated with respect, since the spiritual growth of the entire group is left in their hands (Stock, 1996:12). Quaker life revolves around meeting for worship (Stock, 1996:10). There are no appointed clergy members or religious symbols. Meetings are the responsibility of the entire group where all positions given are those of responsibility, not

authority. Meetings are held in a meeting house and the public is welcome (Stock, 1996:11). During a Quaker meeting, pressing issues are discussed and these conversations are recorded within the Meeting Minutes.

Quakers are known for their simple lifestyles and rejection of the idea of "wealth" and differential status between members (Start and Kirk, 1998:173). Following this theme of simplicity even in death, gravestones are not used as a form of distinguishing between the rich and the less fortunate. Over the years, several allowances were made and Friends were left at liberty to adopt the use of stones in any of their burial grounds (Stock, 1996:19). However, it was understood that the stones had to be uniform in shape, size, and material. These allowances varied between Quaker organizations. Furthermore, Quakers are cautioned against imitating mourning customs of the "outside world" during funerals. Within the burial ground, graves were usually dug in rows (Stock, 1996:27). With respect to burial style, Quakers were sometimes buried near their relations, but more frequently not.

Quakers believe that any piece of land is acceptable for a burial ground since "all land is God's land" (Stock, 1996:2). In 1663, the Society of Friends leased and purchased a piece of land on London Road, Kingston-upon Thames (Figure 3.1) for use as a burial ground (Bashford and Pollard, 1998:155). A year later, Ann Stevens was the first person to be interred within the burial ground. In 1814, the final interment was made and this cemetery located in the south-west part of London fell out of use (Bashford and Pollard, 1998:155).

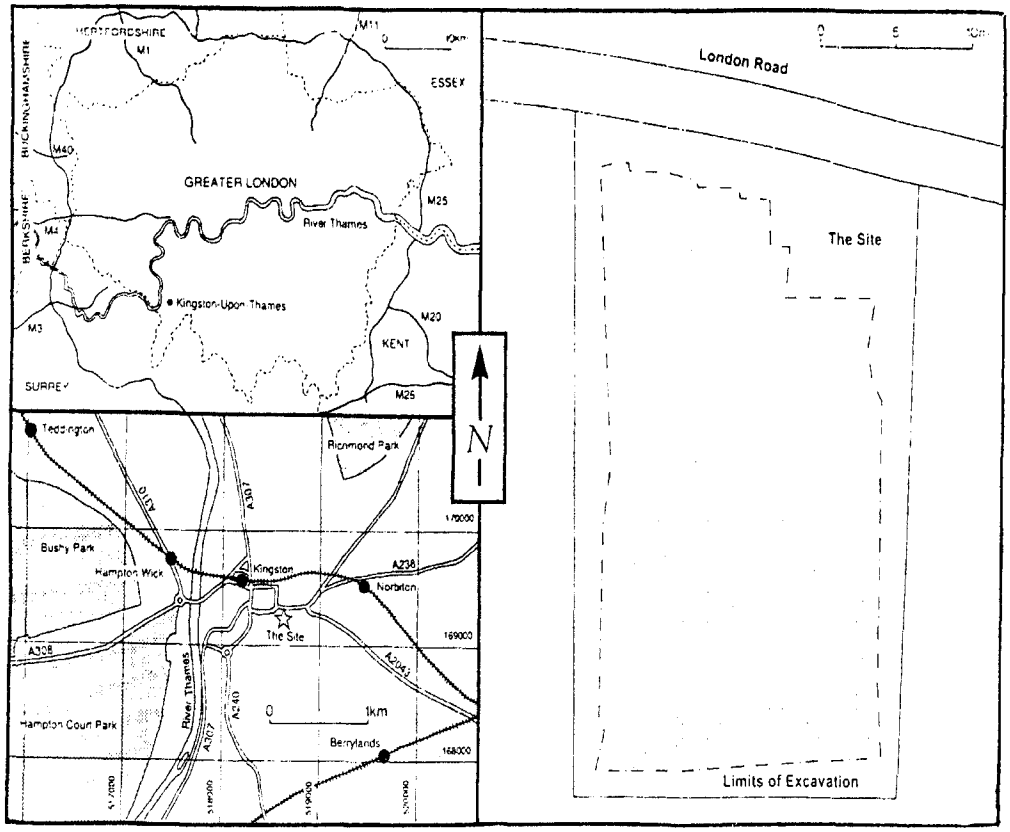

Figure 3.1. Map showing location of the Quaker burial ground within Kingston-upon Thames, Greater London (as adapted from Kirk, 1998:298).

Prior to its closure, the boundaries of the burial ground were expanded on several occasions: 1663, 1687, 1691, and 1739. Recently, the prospect of development motivated the excavation of the post-medieval Quaker burial ground (Bashford and Pollard, 1998:154).

In 1993, the site's role as a Quaker burial ground was confirmed after the area was surveyed and the Museum of London Archaeology Service dug two test trenches (Bashford and Pollard, 1998:154). However, it was not until the Autumn of 1996 that the human remains were removed. Over a period of ten weeks, the first major excavation of a

Quaker burial ground took place (Kirk, 1998:303). Individuals were found mostly with arms by the side. However, on occasion an individual was found buried with their arms or legs crossed (Kirk, 1998:299). The remains of children were found scattered throughout the burial ground suggesting that there were not specialized areas within the site for specific individuals or groups. Historical documents reveal that more than 497 individuals were once buried at the site (Start and Kirk, 1998:167). However, only 360 individuals were removed during excavation. Of the sample, 295 adults were recovered along with sixty-five subadults. The sample consisted of 265 skeletons of known sex (157 females and 108 males) whereas the sex of ninety-five individuals remained undetermined (Start and Kirk, 1998:168). During the excavation, a plan of all the burials was recorded (Figure 3.2). Throughout the excavation, the first features exposed were two brick-built structures recognizable as a burial vault (Figure 3.2A).

3.1.1 BARNARD BURIAL VAULT

According to Quaker beliefs, as described within the pages of *The Book of Discipline*, gravestones were not to be used. Furthermore, part of *The Book of Discipline* describes how graves should not be disturbed and new graves should not crosscut earlier ones (Stock, 1996:18). However, on occasion, as in the Quaker burial ground at London Road, a burial vault was built. Evidence from graves and historic records suggest this vault was constructed by Thomas Barnard, a linen draper, in 1744 (Bashford and Pollard, 1998:161).

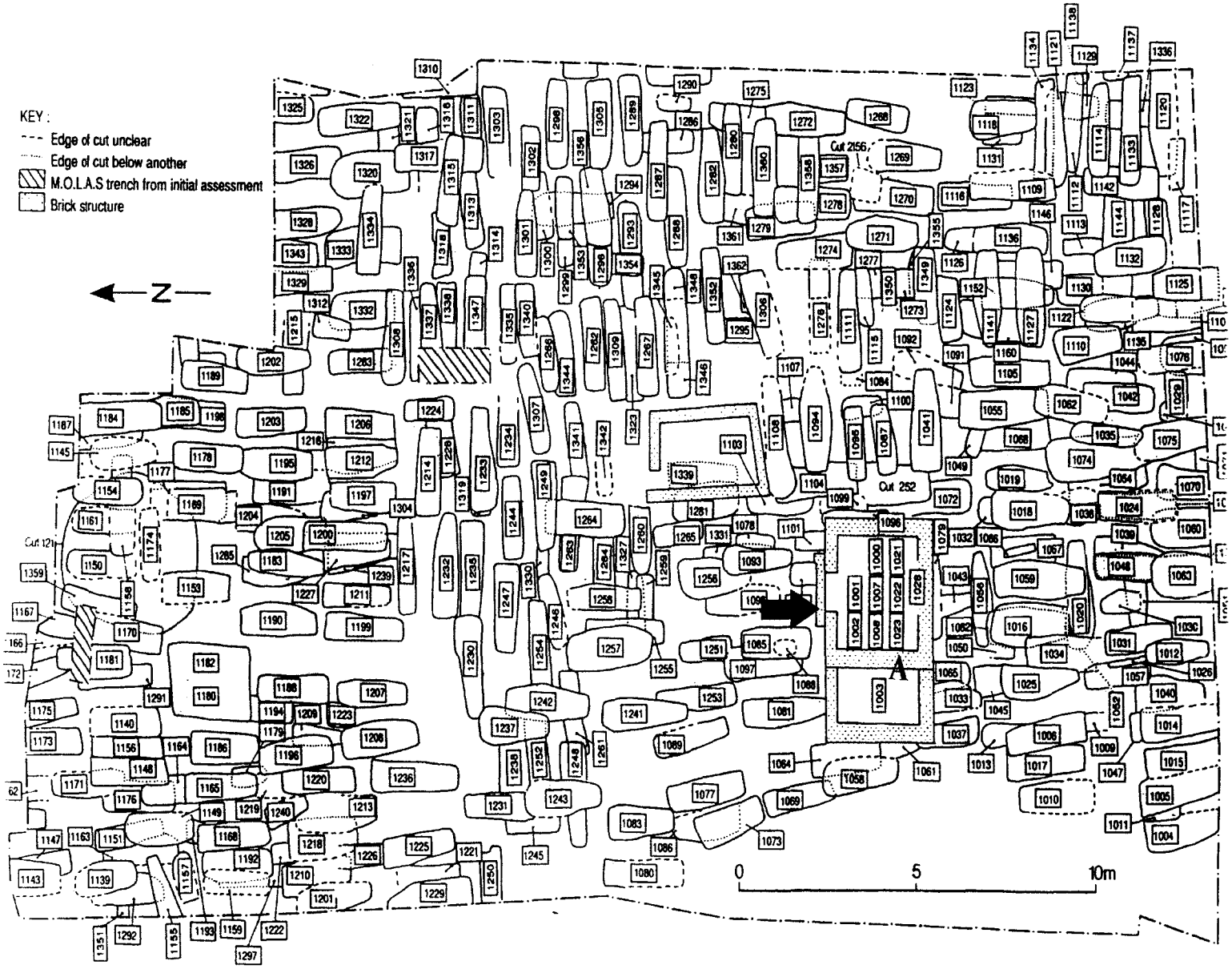

Figure 3.2. Plan of burials found within the Quaker burial ground at Kingston-upon Thames, London England (as adapted from Figure 12.2 of Bashford and Pollard, 1998:157 illustrated by Rob Groller).

Excavation revealed that the Barnard vault was built cutting over earlier burials. According to historical records, Thomas Barnard paid an equivalent of twenty-two dollars to the Quaker meeting for allowing him to build the vault (Bashford and Pollard, 1998:161). It is unknown whether this payment was a bribe or payment in advance for the sin of vanity. Thomas Barnard was not the only Quaker guilty of disobeying Quaker customs. Other instances of grave crosscutting were recorded throughout the grounds as in burials 1020, 1052, 1048, 1053, 1122, and 1135 (Bashford and Pollard, 1998:156).

The Barnard family vault contained the remains of ten individuals including John Barnard, member of parliament for London and Mayor of the city in 1737 (Figure 3.3).

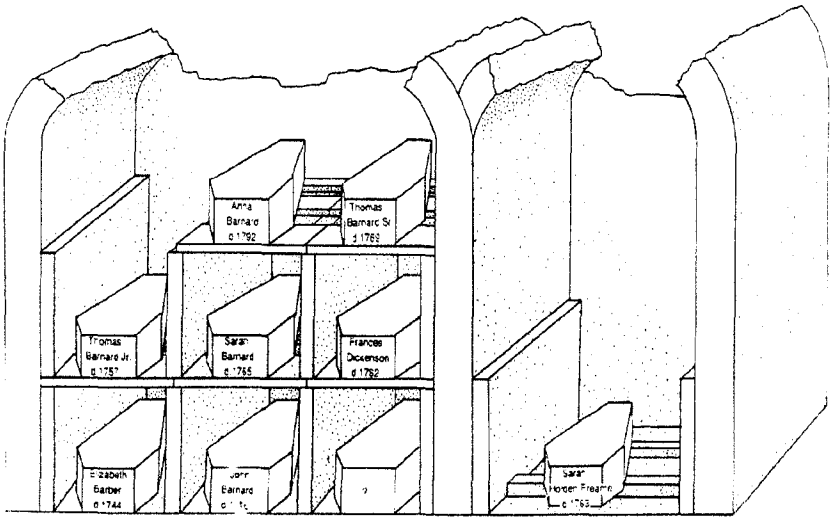

Figure 3.3. Illustration of what the Barnard family vault would have looked like (as adapted from Figure 12.4 of Bashford and Pollard, 1998:158)(illustration: Rob Goller)

Three generations of Barnard family members were found within the brick-built burial vault located at the southern end of the site (Kirk, 1998:301). Details concerning familial relationships are shown in Table 3.1.

Table 3.1 Relationships of those buried within the Barnard family vault (as adapted from Bashford and Pollard, 1998:161).

Family Member	Familial Relationships
Thomas Barnard (1727-1757) 29-30 years ***1000***	Son of Thomas (1002) Brother to Frances (1038), Elizabeth (1021) Uncle to Sarah (1003)
Thomas Barnard (1675-1769) 93-94 years ***1002***	Father of Frances (1038), Elizabeth (1021), Thomas (1000) Grandfather to Barber (1028) and Sarah (1003)
Sarah Holden Dickenson/Freame (d. 1763) 22-23 years ***1003***	Daughter of Frances (1038) Granddaughter of Thomas (1002) Niece to Elizabeth (1021) and Thomas (1000) Cousin to Barber (1028) Great niece to John (1022)
Elizabeth Barnard (1720-1743) 22-23 years ***1021***	Mother to Barber (1028) Sister to Frances (1038), Thomas (1000) Aunt to Sarah (1003)
John Barnard (1672-1747) 74-75 years ***1022***	Brother to Thomas (1002) Uncle to Frances (1038), Elizabeth (1021), Thomas (1000) Great Uncle to Barber (1028) and Sarah (1003)
Barber Barnard (1741-1743) Juvenile 1-2 years ***1028***	Child of Elizabeth (1021) Grandchild of Thomas (1002) Niece/nephew to Frances (1038), Thomas (1000) Cousin to Sarah (1003) Great niece/nephew to John (1022)

All members of the Barnard family were buried in lead coffins. The body of Sarah Holden Dickenson/Freame (d. 1763) was discovered in an annexe constructed adjacent to the Barnard vault (Bashford and Pollard, 1998:158).

Skeletal remains of several members of the Barnard family were retained by Bournemouth University including Thomas Barnard (1727-1757), Thomas Barnard (1675-1769), Sarah Holden Dickenson/Freame (d. 1763), Elizabeth Barnard (1720-1743), John Barnard (1672-1747), and Barber Barnard (1741-1743). The Barnard vault also yields evidence concerning 18th century body snatching. The lead coffin belonging to Anna Barnard (d. 1792) showed signs of forced entry. The only contents of the coffin were remnants of what may have been a blond wig (Kirk, 1998:301). Anna Barnard was the last member of the Barnard family to be placed within the family vault.

3.1.2 OSTEOLOGICAL ANALYSES

Historical documents and osteological evidence suggest that members of the Society of Friends commonly held mercantile occupations similar to those of the parishioners of the St Augustine the Less church. In other words, skeletal evidence revealed that those buried within the cemetery were prosperous, middle-class individuals holding positions such as mariners, tylers, merchants, and shipwrights. Eighteenth-century historical documents reveal that on occasion a non-Quaker was interred within the burial ground. The burial registers record the interment of rich merchants and the spouses of

members of the Society of Friends marrying outside the Quaker community (Bashford and Pollard, 1998:159,164). Judging from the evidence, a historical picture is painted showing a self-sufficient community having close relations with other religious groups.

Using non-metric traits, Start and Kirk (1998) analysed the skeletal remains for evidence of familial relationships and intergroup relatedness. They discovered a degree of relatedness, agreeing with historical accounts suggesting that marriage within the group was encouraged (Start and Kirk, 1998:171). While analysing the remains found within the Barnard family vault, Start and Kirk (1998) noted the occurrence of an extra vertebral segment within several members of the Barnard family. However, Start and Kirk (1998) do not mention in which burials the extra vertebral segments were found. This will become important later within the discussion.

Judging from the skeletal evidence, Quaker beliefs of leading a simple lifestyle affected their diet (Start and Kirk, 1998:173). Members of the Society of Friends presented little tooth decay. A traditional Quaker diet would have likely included less sugars and highly processed carbohydrates such as white flour. Furthermore, aspects of health, disease, and trauma were considered during the analysis. An overall absence of disease which manifests on the skeleton and other health issues was used to suggest that the Quakers buried within the site at Kingston-upon Thames led remarkably healthy lives. However, there were two examples of possible pathology. An adult male displayed one of the most advanced cases of venereal syphilis ever discovered in an archaeological context

(Start and Kirk, 1998). Furthermore, excavators discovered four whole walnuts within the coffin of an individual. The walnuts were placed within the mouth, between the knees and feet while the fourth was somehow displaced from its original position. In folk medicine, walnuts are considered as a sign of mental illness (Start and Kirk, 1998).

Following Start and Kirk's original analysis, at the request of the present-day Quaker Community, a significant portion of the remains have been cremated and re-buried (Bashford and Pollard, 1998:163). Of the original 360 individuals, only fifty-three skeletons remain of the collection which the School of Conservation Sciences holds at Bournemouth University. The present-day Quaker community (Kingston Friends Trusts) granted the University permission to retain all bones excavated which exhibited pathological change (Bashford and Pollard, 1998:163). Since only pathological cases were kept, a form of bias has been added to this study.

3.2 ST AUGUSTINE THE LESS

The city of Bristol, originally *Bright Stow,* is located at the junction between the Avon and Frome rivers (Figure 3.4)(Harvey, 1906:3). The first historical reference to the city of Bristol dates to about 1000 A.D. (Freeman and Hunt, 1887:1). This port city was prosperous and became one of the great towns of medieval England, recognized for its parish churches. Bristol is also a city noted for its commerce and shipping and its role in the development of the regional and international economy (Harvey, 1906:15).

During the 13th century, Bristol began to expand as the result of the diversion of the Frome River. The new river course expanded trade and later led to an increase in population within the area of College Green (Boore, 1998:21). Here, in 1240 A.D., William of Bradeston founded the St Augustine the Less church in order to deal with an increasing local population (Figures 3.4 and 3.5)(Harvey, 1906). Parishioners were interred within the church burial vaults and in the burial ground surrounding it.

During the 15th century the church required restoration (Boore, 1985:22). At the beginning of the 17th century the church registers record more burials than usual. Extra burials may have bee the result of an outbreak of the bubonic plague (Boore, 1985:22). During the 18th and 19th centuries more repairs were made to the parish church of St Augustine the Less. At this time, vault burial inside the church ceased to be used because of health concerns (Boore, 1985:22). As a result, extra burial structures were added-on next to the parish. Only wealthier parishioners could afford to be interred within the burial vaults.

The 19th century saw an increase in population within the town of Bristol. Because of overcrowding, the chapel of St. George Brandon Hill was consecrated in 1823 (Dawson, 1981:22). The chapel of St. George Brandon Hill is shown in Figure 3.6 and is referred to as Sextons Cottage. In 1868 the Royal Hotel was built, encroaching upon the land that the church of St Augustine the Less was built (Figure 3.6)(Boore, 1985:23). Furthermore, part of the churchyard was removed to build the Anchor Road.

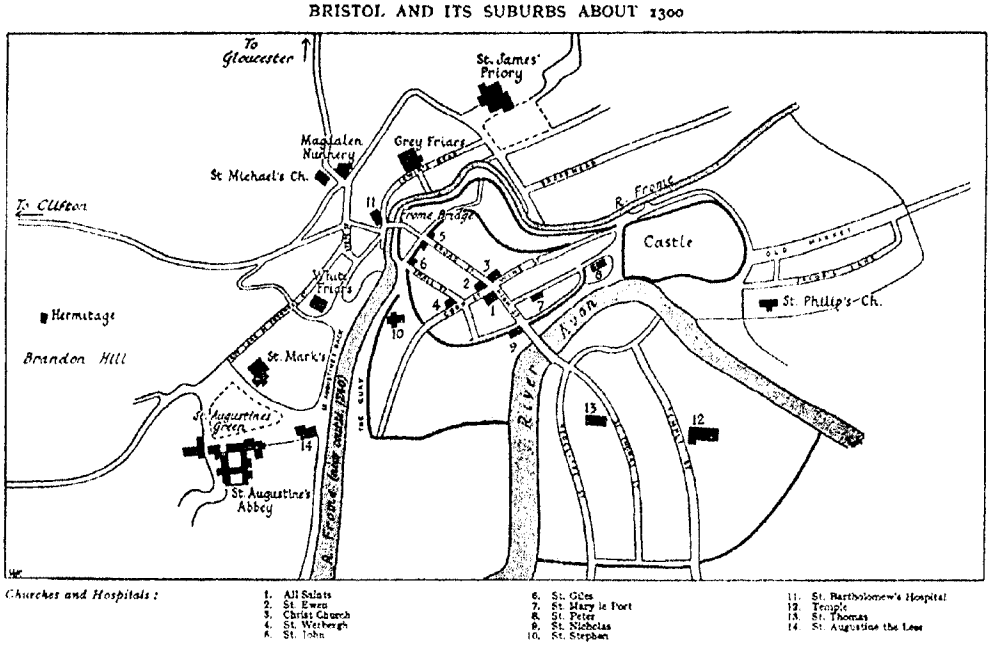

Figure 3.4. Map showing the suburbs of Bristol in the 1300's and the location of the St Augustine the Less Church (14)(as adapted from Smith, 1970:2).

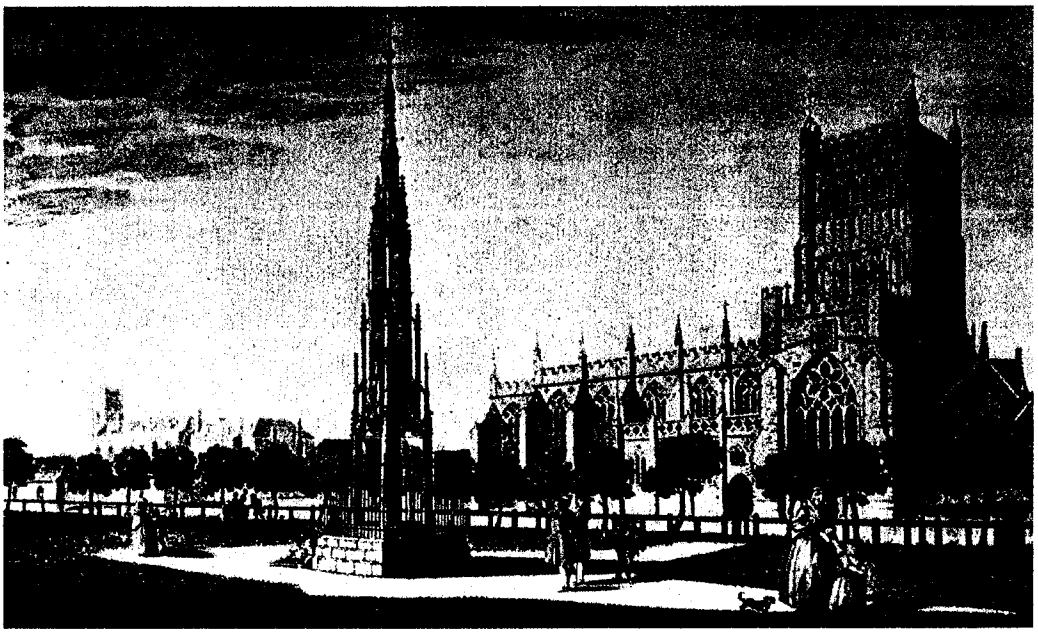

Figure 3.5. An eighteenth century representation of the St Augustine the Less church, Bristol, England (as adapted from McGrath, 1972:31).

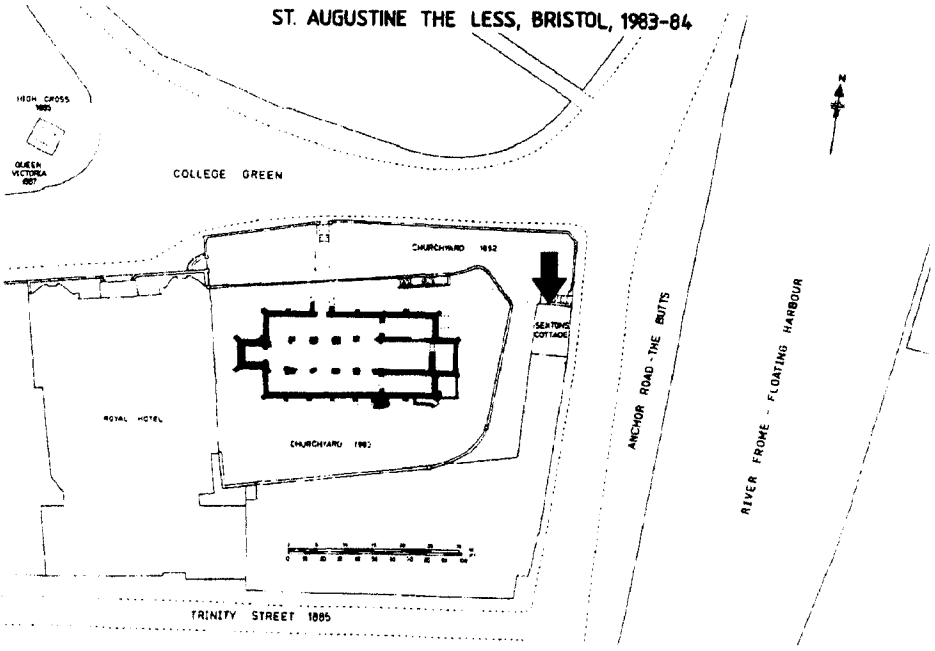

Figure 3.6. Drawing showing the location of the St Augustine the Less site within present-day Bristol (as adapted from Figure 3 of Boore, 1985:22).

Because of this, many eighteenth-century burials were exhumed in 1892. Two years later, many more nineteenth-century graves were removed to once again widen Anchor road. In total, over two-thousand eighteenth and nineteenth-century burials were removed. It is not mentioned within the literature where the remains were reburied.

The 20th century saw a decrease in activity within Bristol. Attendance at the church of St Augustine the Less was at an all-time low. Due to falling congregations, the parish of St Augustine the Less was united with St. George on Brandon Hill in 1938. Soon after the church of St Augustine the Less was damaged by fire during the second

World War (Boore, 1998:68). These events led to its eventual closure in 1956 and its demolition in 1962 (Dawson, 1981:22). At the time of its demolition, the church of St Augustine the Less was taken down to ground level (Figure 3.7).

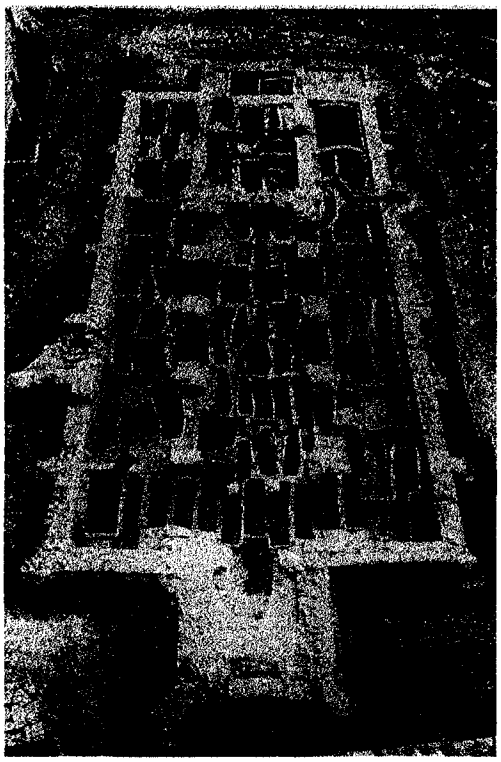

Figure 3.7. Plan of the burials located within the church of St Augustine the Less (as adapted from Plate 1 of Boore, 1985:26).

During this time, several burials found within the church were transferred to the Canford cemetery to be re-interred (Boore, 1983:2). However, it was not until 1971 that the external churchyard was cleared of its remaining graves (Boore, 1983:1).

Little is known of the individuals buried within the former church of St Augustine the Less in Bristol. However, in the winter of 1983-1984, excavations began on the site of the ancient church in advance of land sale and development (Boore, 1998:67). The objectives of the excavation were to survey and record the surviving remains of the church and churchyard (Boore et al., 1989:247). Historical documents revealed a temporal sequence spanning more than 700 years for the use of the church for burial of the dead (Boore, 1985). This sequence goes as far back as the saxo-norman period (c.11th-12th centuries) followed by the medieval (c.13th-15th centuries) and post-medieval historical periods (c.16th-17th centuries) to as recently as the nineteenth century (Boore, 1998:70). Within the church, both brick and burial vault graves were used, suggesting that there existed some form of differential status among those buried within (Ponsford et al., 1989:254).

Several vaults were recorded and were found crammed within the church (Boore, 1985:29). It was during the post-medieval period that the church attained its greatest use, as suggested by concentrations of burials (Boore, 1986:213). Church documents were discovered providing information concerning the trade of its middle-class parishioners. Trades listed include shipwrights, mariners, hoopers, "tylers," bakers, pipemakers, merchants, and surgeons (Boore, 1985:22). Several artefacts were discovered within the burials including pottery, floor tiles, coins, tobacco pipes, tokens, and post-medieval decorated window glass (Boore, 1998:70).

3.2.1 OSTEOLOGICAL ANALYSES

In 1999, O'Connell analysed the skeletal remains recovered from the church of St Augustine the Less during the 1983-84 excavations. More than 100 burials were recorded (Boore, 1986:213). From these, 119 individuals were recovered (O'Connell, 1999:i). The sample consisted of ninety-nine adults and twenty juveniles in varying states of preservation. O'Connell (1999) analysed the skeletons for the presence of several pathological conditions including fractures, dental caries and calculus, joint, metabolic, and infectious diseases. Several more obvious developmental defects were recorded including spina bifida and sacralization of the fifth lumbar vertebra (O'Connell, 1999:i).

For this research, both skeletal samples were particularly interesting in that initial osteological analyses carried out by Start and Kirk (1998) and O'Connell (1999) provided some indication that developmental conditions were present. Furthermore, both samples are derived from two entirely different social contexts, the Quakers representing a genetically isolated population whereas the parishioners of the St Augustine the Less church are believed to have originated from diverse genetic backgrounds (Start and Kirk, 1998 and O'Connell, 1999). Therefore, each collection offered a potential opportunity to study defect frequencies in an isolated and assorted gene pool respectively. The Quaker skeletal sample also presented an aspect not typically found within an archaeological context: church records identifying several individuals as well as some family relationships.

CHAPTER 4: METHODOLOGY

4.1 INTRODUCTION

In order to gather data from both skeletal samples, Barnes' (1994) pioneering work in the area of developmental paleopathology has set the stage for the present research. Various scoring techniques were evaluated, based on their ease of use and reproducibility. After intense review, a scientific framework including metric and non metric observations was compiled, building from the earlier work of Barnes (1994)(Appendix A). Both immature and adult skeletons of both the Quaker and St Augustine the Less collections were analysed within this research, since several developmental anomalies are not present exclusively in adult skeletons but are present *in utero* and at birth. The analysis of both collections was carried out by the author, within the Forensic Archaeology and Anthropology Lab at Bournemouth University, England where the collections are housed. Sex and age of each individual was assessed. Sex designations and age approximations of the skeletal remains were obtained from the original skeletal inventories of each collection (Start and Kirk, 1998; O'Connell, 1999).

4.2 SEX DESIGNATIONS

The sex of each individual was reassessed using morphological features of the skull, innominates, and sacrum presented by Schwartz (1995). Several of the criteria proposed by Schwartz (1995) were used to arrive at a more reliable sex estimate. Sex determinations were based on macroscopic criteria only. A skeleton was designated as

Female or Male if it presented several of the possible morphological indicators of a particular sex. Several individuals were assigned to the F?, M?, or ? (indeterminate) categories when incompleteness, poor preservation, or mixed sex features prevented an accurate sex assessment. To facilitate the following discussion and to maximize sample sizes, the F? and M? individuals were treated as Female and Male respectively. Similarly, subadult skeletons not manifesting typical sex characteristics were placed in the no gender/unknown sex category.

4.3 AGE ANALYSIS

Age at death of the skeletons was reevaluated using standard osteological techniques (Lovejoy et al., 1985; Brooks and Suchey, 1990; Buikstra and Ubelaker, 1994). Individuals from both skeletal collections were placed within one of the following broad age categories: fetus (before birth); neonate (birth-11 months); infant 1 (1-5 years); infant 2 (6-11 years); juvenile (12-17 years); young adult (18-29 years); prime adult (30-44 years); and mature adult (45+ years). These broad age categories were adapted from Start and Kirk (1998). Individuals from both the Quaker burial ground and St Augustine the Less church were assigned to similar age categories to facilitate comparisons. Age categories were also used since the fragmentary nature of many of the remains precluded an accurate age assessment to year.

4.4 DEMOGRAPHIC COMPOSITION

Of the original Quaker and St Augustine the Less collections, 81 skeletons (81/132 =61%) were complete enough for the purpose of this research (N = 81). In spite of the completeness of other skeletal portions, a skeleton was considered whole if it contained more than four complete vertebrae, portions of the exoccipitals, and/or fragments of ribs. This may seem to be a minimal set of requirements. However, in order to maximize sample sizes, some allowances have been made which will be taken into consideration in the discussion to come.

Fifty-two Quaker skeletons were examined and only 39 (39/52 = 75%) were included in the analysis (N=39). Only 53% of individuals from the St Augustine the Less collection (42/80) were considered complete (N=42). In the case of several St Augustine the Less burials (1,3,10,12-14,27-32, 45-46), circumstances precluded the recovery/examination of human remains. Furthermore, several of the St Augustine the Less and Quaker burials were on loan to another institution and were not available at the time of the examination. These will not be included in the following discussion. These circumstances led to smaller sample sizes than expected.

The Quaker sample consisted of 15 females, 20 males, and 4 individuals of undetermined sex. At the time of death, individuals ranged in age from 1 (infant 1) to greater than 45 years (mature adult). The St Augustine the Less church sample consisted of 9 females, 26 males, and 7 individuals of undetermined sex ranging in age from 6 to greater than 45 years. Previous work and historical records indicate that the St Augustine

the Less burials were associated with four time periods: the saxo-norman (2) period followed by the medieval (17) and post-medieval (16) historical periods to as recently as the eighteenth and nineteenth centuries (7). Sex and age distributions for both collections are shown in Table 4.1.

Table 4.1 Age and sex distributions for the Quaker and St Augustine the Less skeletal collections.

Age Category	Kingston Upon Thames (Quakers)			St Augustine the Less		
	Frequency			Frequency		
	Male	Female	Unknown	Male	Female	Unknown
fetus (before birth)	0	0	0	0	0	0
neonate (birth-11 months)	0	0	0	0	0	0
infant 1 (1-5 years)	0	0	1	0	0	0
infant 2 (6-11 years)	0	0	0	0	0	2
juvenile (12-17 years)	0	1	3	0	0	0
young adult (18-29 years)	3	2	0	8	0	0
prime adult (30-44 years)	6	4	0	9	3	1
mature adult (45+)	10	7	0	7	4	3
undetermined adult	1	1	0	2	2	1
Totals	20	15	4	26	9	7

4.5 SKELETAL ANALYSES

Prior to examination of the skeletons for developmental defects, an inventory was taken of the vertebral, costal, and cranial material present. This was accomplished by first putting the vertebrae and ribs in anatomical order using standards presented by Schwartz

(1995). Fragments were identified using a reference collection and photographs provided by Abrahams et al. (1998). During the assessment of the crania, ribs, and vertebrae, pathological cases were established in order to distinguish between developmental and pathological processes. Here, the pathological descriptions presented by Ortner and Putschar (1985) were used. This was carried to ensure that anomalous expression or asymmetry were not the result of pathological processes, but of congenital etiology (Shore, 1930:208). Each skeletal part was inspected and/or measured for developmental defects and scored based on the compiled framework (Appendix A). Besides general scores, the location of each anomaly was recorded where detailed descriptions were written and photographs taken using a Sony Cybershot DSCP32 3.2MP digital camera.

4.6 DATA COLLECTION

A combination of measurements and non-metric scales were used to determine the presence, absence, and/or varying degrees of expression of the developmental anomalies of the vertebral column, ribs, and exoccipitals.

Scales. For those anomalies where development was continuous and where presence could not be determined metrically, a graded scale was used representing expression in human remains. In general, scales are based on the anomaly's location (i.e., bilateral, unilateral, medial, anterior, posterior), severity (i.e., complete versus mild expression), size (i.e., small, medium, large), or its relation to other skeletal elements. For

example, there are four classes of cervical ribs (1= bony tubercle; II = blunt 40-50mm projection; III = rib extension without costal joint; IV= complete with costal joint; V= mild expression)(Barnes, 1994:131)(Appendix A). These inborn errors are expressions of cranial shifting at the cervicothoracic border. Several other defects were treated in a similar way such as rib abnormalities, Klippel-Feil syndrome, and epitransverse processes (Appendix A).

Absence or presence. Certain discrete anomalies could not be recorded using a scale, therefore, only absence or presence was recorded. For example, coronal cleft centrum, a rare notochord defect, was scored based on presence or absence (Barnes, 1994:40)(Appendix A). Referring to Appendix A, other traits were recorded based on a presence or absence basis such as odontoid displacements, block vertebra, and numerical errors in segmentation.

Measurements. The observation and measurement of certain anomalies were carried out using spreading and sliding calipers. For example, underdevelopment of the centrum (centrum hypoplasia) was determined by taking anterior and posterior measurements of the vertebral bodies (Appendix A). Measurements were recorded to the nearest millimetre. Anterior body height was taken in the midline from the superior to inferior margins of the anterior side of the centrum using spreading calipers (Schwartz, 1995:328). Similarly, posterior vertebral body heights were taken from the midline of the

posterior side of the centrum using spreading calipers (Schwartz, 1995:328). Following this, an anterior/posterior ratio was calculated. Any vertebral body presenting a ratio of more than 1.3 was designated as hypoplastic (Shore, 1930). After a designation was made, the area of hypoplasia was determined (i.e., anterior versus posterior hypoplasia). As shown in Appendix A, similar measurements were also taken to reveal the presence of hemivertebrae.

4.7 DATA ANALYSIS

For both collections, all metric and non metric data were recorded and placed in the appropriate sections of the prepared data sheets (Appendix A). Variables including sex, age, and individual scores were entered into the Statistical Package for the Social Sciences (SPSS) Version 9 (1998).

For the St Augustine the Less collection, the preservational state of several of the skeletal remains led to small sample sizes inhibiting the use of more complex statistical tests. Therefore, measures of central tendency (frequencies and means) were employed to suggest possible trends in the development of defects when sample sizes were too small to allow statistical tests such as independent t-tests. Independent t-tests were used when sample sizes satisfied the requirements of the test. Components of interest within this preliminary analysis include: the degree and range of sex differences of each trait, age predilections, inter-trait associations, and temporal trends. As stated above, this was carried out to determine whether any patterns or trends exist within the populations or

individuals, between the sexes, and across age categories. Furthermore, because of small sample sizes, it was impossible to compare individuals from different time periods beyond the use of frequencies.

As previously mentioned, only the skeletons of Quaker individuals showing interesting pathology were kept by the School of Conservation Sciences at Bournemouth University, England. As a result, this sample may not be representative of the entire population from which it is drawn. Because the Quaker collection is not representative because of its non-randomness, tests for statistical significance do not allow one to generalize beyond this particular sample of skeletons. Therefore, in most cases only frequencies and means (measures of central tendency) were employed to suggest possible trends in the development of defects within this collection. As in the case of the St Augustine the Less collection, patterns of interest include sex and age ranges of each trait and any visible association between individual traits.

CHAPTER 5: RESULTS

All vertebrae, ribs, and exoccipitals of the one hundred and thirty-two skeletons from both the St Augustine the Less and Quaker collections were thoroughly examined for the presence of developmental defects. Of the original collection, 81 individuals (N=81) were complete enough for the purpose of this research. The sample consisted of 42 individuals (N=42) from the St Augustine the Less collection (9 females, 26 males, 7 undetermined) and 39 (N=39) from the Quaker burial ground (15 females, 20 males, 4 undetermined). For the following discussion, skeletons from the Quaker burial ground will be referred to as KUT and those of the St Augustine the Less collection as AUG. Defects recorded will be discussed separately for each collection. Furthermore, anomalies discovered will be discussed in the order described in the previous chapters.

Several skeletons were incomplete because of preservation. Therefore, skeletal evidence for a given pathology may not be present for observation. It is possible that the actual number of developmental pathologies presented by individuals from each collection may have been much higher or lower. Furthermore, because of small sample sizes, certain trends in the development of defects may not be visible. Because sample sizes were low, the statistical tests used may not have had the statistical power to detect existing differences. Therefore, it is probable that a false null hypothesis may have been accepted, thereby committing a Type II statistical error. In other words, few significant differences were found, although in reality such differences may have existed.

5.2 QUAKER BURIAL GROUND

As a population sample, presence and frequency of defects for the Quaker sample from Kingston-upon Thames, England are described below.

5.2.1 NOTOCHORD AND NEURAL TUBE DEFECTS

No notochord or neural tube defects were observed on the skeletons of those buried within the Quaker burial ground.

5.2.2 ERRORS IN THE DEVELOPMENT OF THE PARAXIAL MESODERM

When the entire sample of 39 Quaker skeletons was assessed for errors in the development of the paraxial mesoderm, 51% (N=39) of individuals manifested these pathologies. The number of defects exhibited by each individual varied. Twenty-three percent of individuals possessed one error in the development of the paraxial mesoderm while 15% exhibited two defects. Furthermore, 8% of Quaker skeletons exhibited three errors in the development of the paraxial mesoderm, while 5% of the sample possessed four defects.

Between the sexes, males (50%; N=20) displayed a slightly smaller proportion than females (60%; N=15), which was not a significant difference. Furthermore, the skeleton of a subadult of undetermined sex also exhibited an error in the development of the paraxial mesoderm. In calculating age distributions fifty-percent (N=4) of juvenile skeletons from the Quaker collection exhibited a minimum of one error in the development

of the paraxial mesoderm. Furthermore, 40% (N=5) of young adults, 60% (N=10) of prime adults, and 52% (N=17) of mature adults exhibited some form of developmental defect involving the paraxial mesoderm. Additionally, one (N=2) of individual of unknown age were found to have at least one defect of the paraxial mesoderm. No significant differences were calculated.

5.2.2.1 Errors in Segmentation

Errors in segmentation were recorded on the remains of three males (3/20= 15%) and two females (2/15= 13%) from the Quaker burial ground. Sample sizes did not permit the use of complex statistics. Two examples of hemimetamere hypoplasia recorded within the sample. In anterior view, the right superior side of the first sacral segment of a mature female (KUT 1059) appeared underdeveloped (hypoplasia) (Plate 1).

Plate 1: KUT 1059 Photograph of hemimetamere hypoplasia of S1 in a mature female.

Portions of the inferior aspect of this sacrum and coccyx were not recovered. No other vertebral segments were involved and no other observable developmental pathology was noted on this individual.

The fourth thoracic vertebra of John Barnard (KUT 1022) presented a lateral/lateral ratio of 1.4 (Plate 2). The second example of failure of segmentation in the Quaker collection was discovered on the skeleton of a prime adult female (KUT 1023) in the form of Type II Klippel-Feil syndrome (Plate 3). The second and third cervical vertebrae failed to separate, with failure in segmentation between bodies, neural arches, and apophyseal facets.

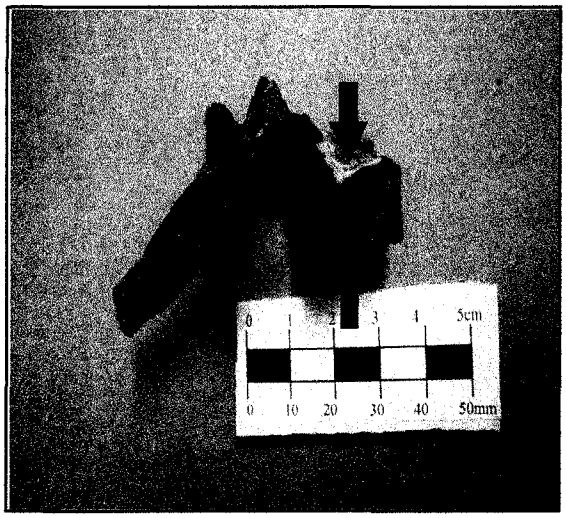

Plate 2: KUT 1022 Photograph showing hemimetamere hypoplasia of the fourth thoracic vertebra of John Barnard.

Plate 3: KUT 1023 Photograph showing Type II Klippel-Feil syndrome.

The preservation of ribs in the Quaker collection was generally poor; many were fragmented where the ends could not be examined for evidence of irregular segmentation.

Therefore, no case of irregular segmentation was recorded within the KUT skeletal collection. Furthermore, no cases of recognizable failure of neural arch joint segmentation or absence of apophyseal facets were observed within the Quaker skeletal collection.

Two examples of numerical errors in segmentation were recorded within the Quaker sample (2/39 = 5%). Extra vertebrae were recorded solely on male skeletons (2/20 =10%). The first case of a supernumerary segment was recorded on the skeleton of a prime adult male (KUT 1019) and the second case was noted on the skeleton of Barnard family member, John Barnard (KUT 1022)(Plate 4).

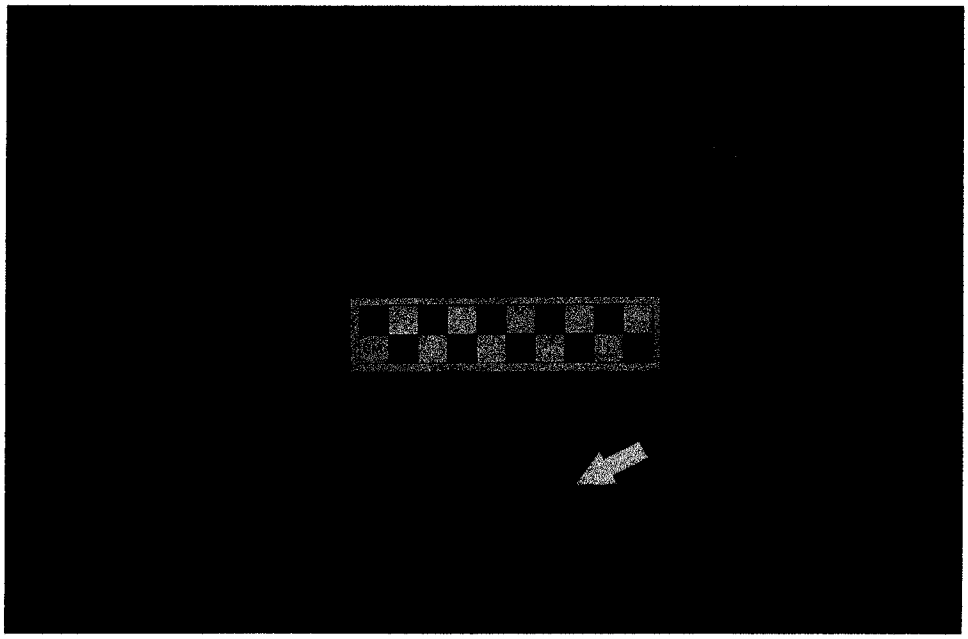

Plate 4: KUT 1022 Photograph showing an extra thoracic segment at the thoracolumbar border in the skeleton of John Barnard.

Both cases of extra vertebral segments (T13) were recorded at the thoracolumbar vertebral border and exhibited thoracic-like characteristics.

5.2.2.2 Failures in Differentiation (Border Shifts)

Evidence for transitional vertebrae resulting from shifting was recorded at all borders excepting the cervicothoracic and sacrocaudal. In total, 16 individuals (16/39 = 41%) exhibited some form of shifting at a minimum of one vertebral border. With regards to incidence, border shifting was recorded in 40% of females (6/15), 45% of males (9/20), and in one individual of undetermined sex (1/4 = 25%). No significant difference was found with regards to sex distribution. Affected individuals ranged in age from juvenile to mature adult. No age group was significantly affected more than another.

Twelve cases of cranial shifting (75%), three instances of caudal shifting (19%), and one case of shifting in both directions (6%) were recognized. An independent t-test revealed that cranial shifting was recorded more often than caudal ($t=2.317$, $p< .05$). No significant difference in direction of shifting (cranial versus caudal) was calculated when male and female skeletons were compared. More cases of shifting were recorded in the skeletons at the occipitocervical vertebral border (38%, N=39) compared to any other (cervicothoracic= 0%; thoracolumbar= 5%; lumbosacral= 3%; and sacrocaudal= 0%).

1. Occipitocervical border

At the occipitocervical border, 15 cases of mild expressions of shifting were recorded within the KUT collection (15/39 = 38%). Cranial shift was recorded at an incidence rate of 33% (N=39). Three examples of precondylar tubercles (3/39 = 8%) were recorded in the skeletons of a juvenile female (KUT 1077b: 1/15= 7%) and two males

(KUT 1019- prime adult, KUT 1141- mature adult: 2/20 = 10%). All precondylar tubercles were medianly-positioned and trace in size (Plate 5). Evidence of mild cranial shift at the occipitocervical border was also recorded in the form of an incomplete transverse basilar cleft (Plate 6). The cleft was recorded on the right side of the basilar portion of the occipital bone of a mature adult female (KUT 1067).

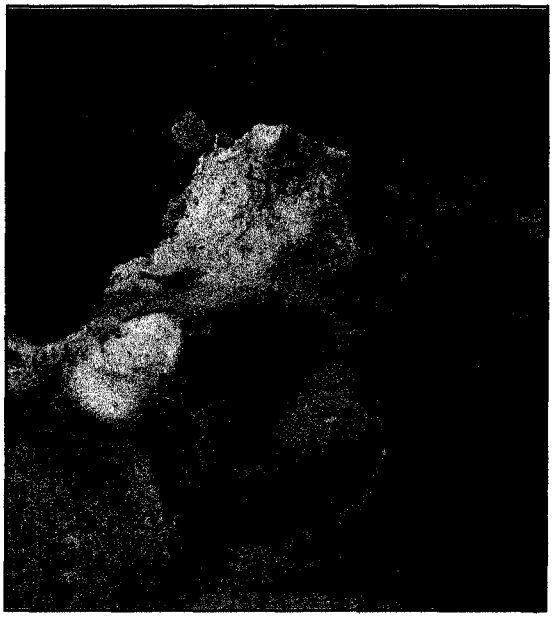

Plate 5: KUT 1019 Photograph showing a medianly-positioned trace precondylar tubercle (male, prime adult).

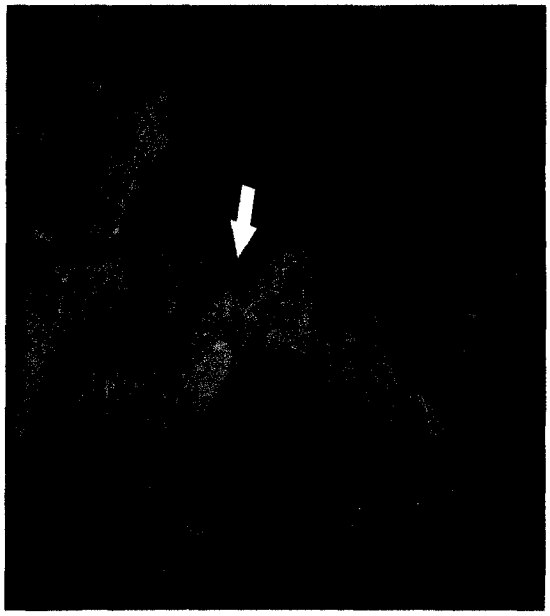

Plate 6: KUT 1067 Photograph showing a unilateral transverse basilar cleft (female, mature adult).

Variation in the occipital condyles was recognized within the Kingston-upon Thames collection. Both incomplete and complete types of bipartite occipital condylar facets were recorded. One example of complete bilateral bipartite occipital condyles was recorded in a mature male (KUT 1074)(Plate 7). Incomplete bipartite occipital condylar

facets were recorded in a mature adult female (KUT 1145: 1/15 = 7%)(Plate 8) and in a prime adult male (KUT 1019: 1/20 = 5%).

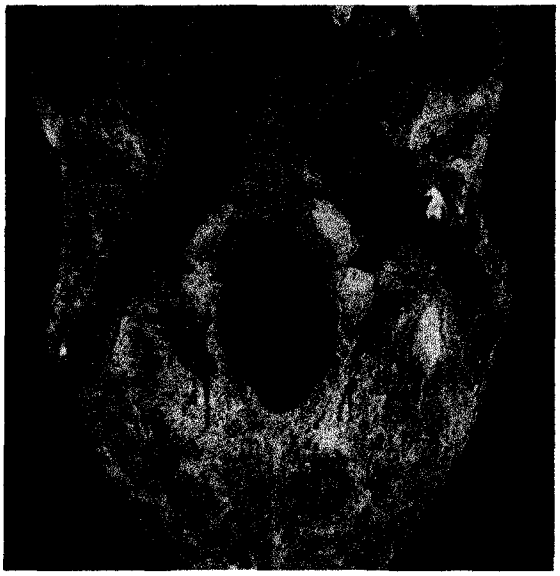

Plate 7: KUT 1074 Photograph showing bilateral complete bipartite occipital condylar facets (male, mature adult)

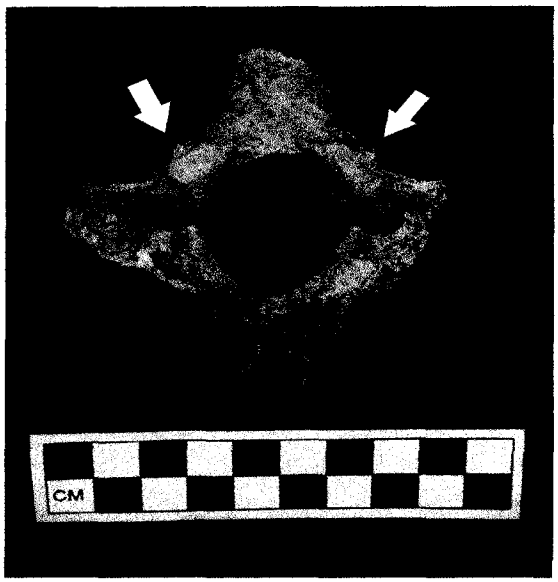

Plate 8: KUT 1145 Photograph showing bilateral incomplete bipartite occipital condyles (female, mature adult)

Only two of the four varieties of divided hypoglossal canals were recorded within the KUT sample. Of 39 skeletons, six individuals (6/39 = 15%) ranging in age from juvenile to mature adult presented either Type I (4/6 = 67%) or Type II (2/6 = 33%)(Plate 9) varieties of bipartite hypoglossal canals. Three females (3/15 = 20%), two males (2/20 =10%), and one individual of undetermined sex (1/1 = 100%) presented these traits. Sixty-seven percent of individuals exhibited divided left hypoglossal canals whereas the remaining individuals were affected on the right (33%).

Plate 9: KUT 1073 Photograph showing Type II bipartite hypoglossal canal (undetermined sex, juvenile).

No example of complete or incomplete caudal shifting at the occipitocervical border, was recorded (occipitalization of the atlas). However, two cases (2/39 = 5%) of mild expressions of occipitalization of the atlas were noted: (1) posterior and lateral arch bridging of the first cervical vertebra and (2) hypoplasia of the occipital condyles. As part of the epitransverse process complex, bridging of the arch of the atlas was recorded in four individuals (4/39 = 10%). Lateral arch bridging was noted on the skeletons of two females (2/15 = 13%)(Plate 10). Posterior arch bridging was recorded on the skeletons of John (KUT 1022) and Thomas (KUT 1000) Barnard (2/20 = 10%)(Plate 11). Individuals possessing this trait ranged in age from prime to mature adult and presented all four varieties of this defect (Type I, II, III, IV). One case (3%) of bilateral hypoplasia of the occipital condyles was noted on the skeleton of a young male (KUT 1099)(Plate 12).

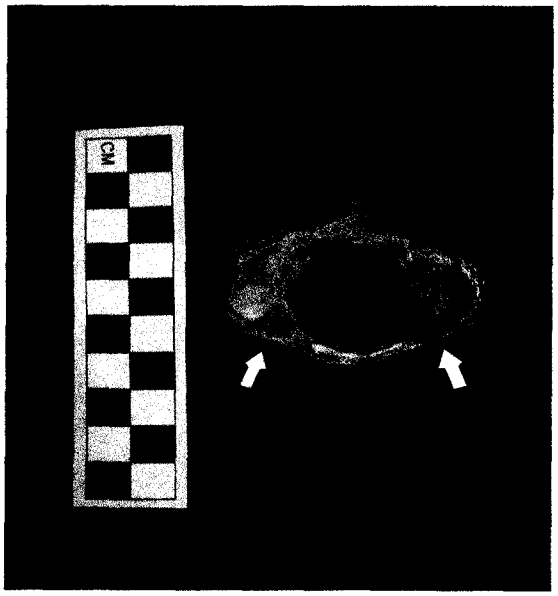

Plate 10: KUT 1142 Photograph showing lateral arch bridging of the atlas (female, mature adult)

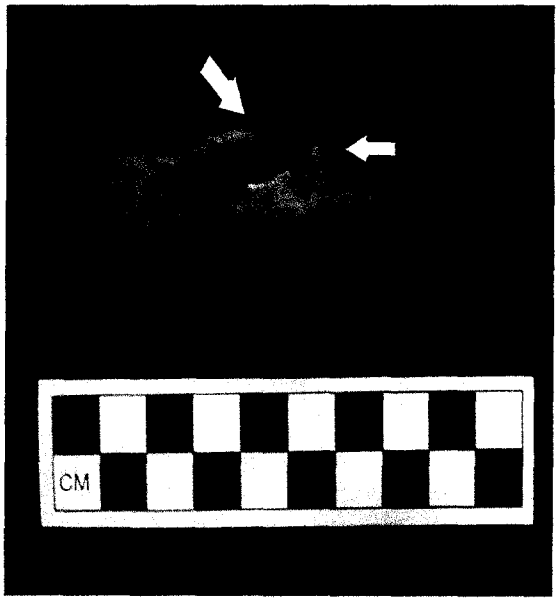

Plate 11: KUT 1022 Photograph showing posterior arch bridging on the atlas of John Barnard (mature adult)

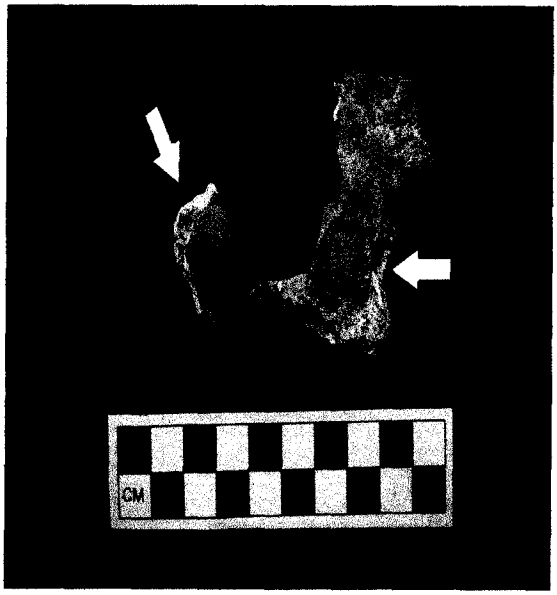

Plate 12: KUT 1099 Photograph showing bilateral hypoplasia of the occipital condyles (young male).

2. Cervicothoracic border

No example of shifting was recorded at the cervicothoracic border.

3. Thoracolumbar border

Two cases (2/39= 5%) of cranial shifting at the thoracolumbar border were recorded. The first case involved a complete expression of shifting in the skeleton of a prime adult female (1/15= 7%)(KUT 1135). In this case, the costal facets for the twelfth ribs were absent and the transitional inferior articular facets were located on T11 instead of T12 (Plate 13). The second case of mild cranial shifting at the thoracolumbar border was noted on the skeleton of a young male (1/20= 5%)(KUT 1005). Here, the transitional inferior articular facets were on T11 instead of T12 (Plate 14). However, this individual possessed costal facets for the twelfth ribs. No example of caudal shifting at the thoracolumbar border was noted.

4. Lumbosacral border

At the lumbosacral border, no evidence of cranial shifting was recorded. However, one example (1/39= 3%) of mild caudal shifting was recognized. The sacrum of John Barnard (KUT 1022) presented an anterior cleft between the first and second sacral segments (Plate 15). No other examples of shifting at the lumbosacral border were noted.

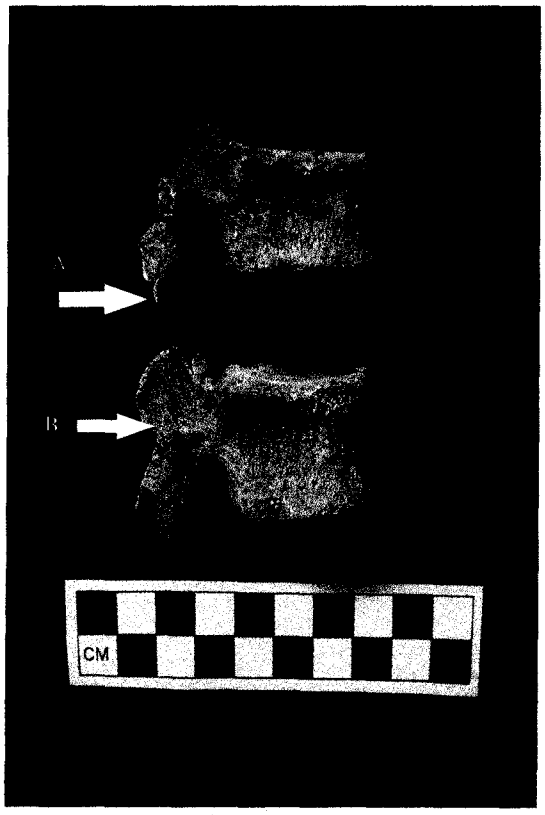

Plate 13: KUT 1135 Photograph showing (A) transitional facets on T11 instead of T12 and (B) lack of costal facets on T12 (female, prime adult).

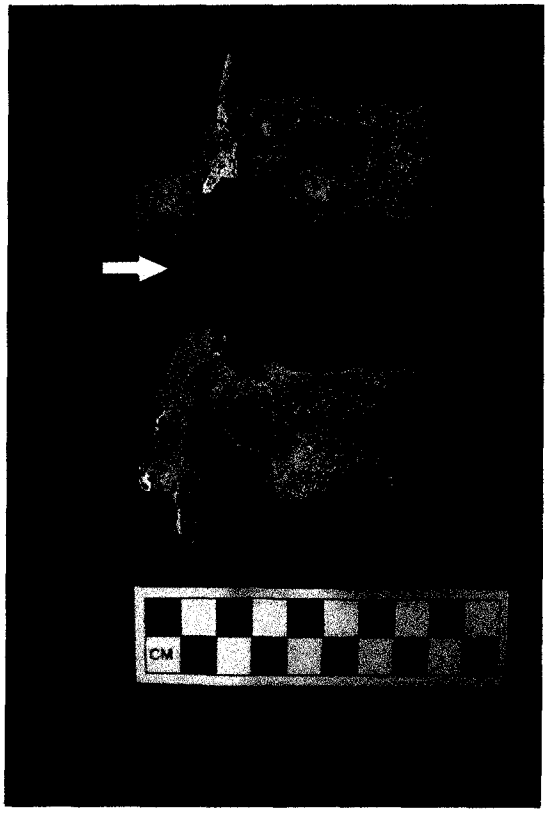

Plate 14: KUT 1005 Photograph showing transitional inferior articular facets on T11 instead of T12 (young male).

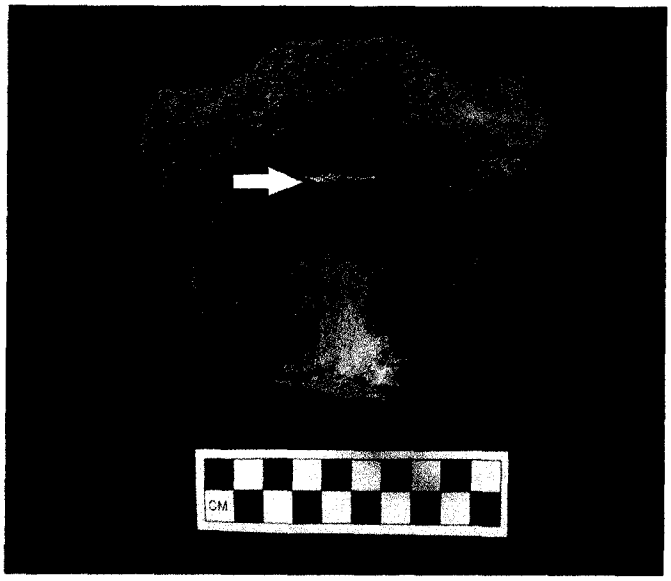

Plate 15: KUT 1022 Photograph showing an anterior cleft between S1 and S2 of John Barnard.

5. Sacrocaudal border

No evidence of shifting was recorded at the sacrocaudal border.

5.2.2.3 Developmental Delay of Structures

Developmental delay of the vertebral elements was recognized in eight individuals from the KUT sample (8/39 = 21%). Of these, four cases (4/20= 20%) were recorded from male skeletons including that of John Barnard (KUT 1022). Male skeletons possessing this trait ranged in age from young to mature adult. The skeletons of four females also showed evidence of developmental delay (4/15 = 27%) ranging in age from prime to mature adult with no one age group more significantly affected than another.

Cleft neural arch was recorded in six individuals (6/39= 15%) from the Quaker skeletal sample. Fifty-percent of the cases of cleft neural arch were recorded in male skeletons (3/20= 15%) ranging in age from young to prime adult. The remaining three cases of cleft neural arch were recorded in female skeletons (3/15= 20%) ranging in age from prime to mature adult. The sacra of four individuals (two males, two females) within the KUT collection exhibited clefting between the first and second sacral segments (Plate 16). Also, the first cervical vertebra of a prime adult male (KUT 1112) presented a cleft. Furthermore, the twelfth thoracic vertebra of a young male (KUT 1099) exhibited a cleft (Plate 17).

Developmental delay in the form of centrum hypoplasia was observed in the remains of four individuals following measurement of the vertebral bodies (4/39 = 10%).

Three of the four cases were recorded in male skeletons (3/20 = 15%) all presenting vertebral body ratios of 1.4. All cases of centrum hypoplasia involved the anterior portion of the vertebral body (Plate 18). Only the fifth and seventh thoracic vertebrae were affected.

Plate 16: KUT 1023 Photograph showing sacral cleft between S1 and S2 (female, prime adult).

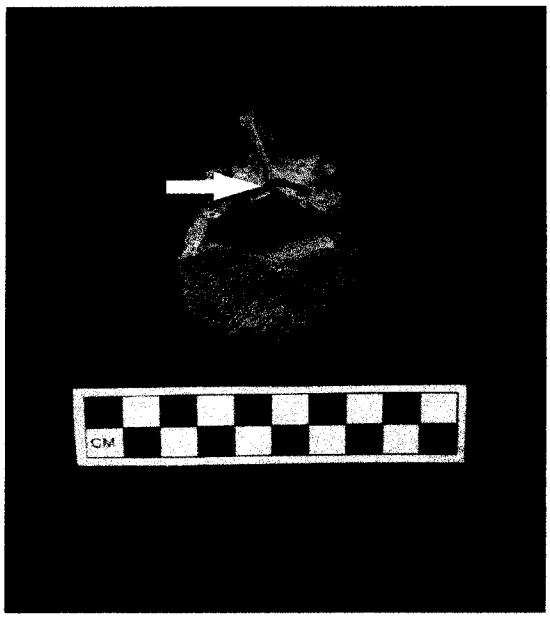

Plate 17: KUT 1099 Photograph showing a cleft in the neural arch of T12 (young male).

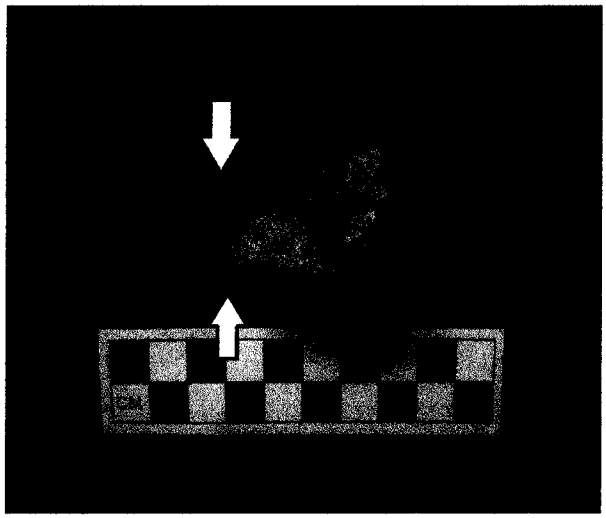

Plate 18: KUT 1112 Photograph showing anterior centrum hypoplasia of the seventh thoracic vertebra of a prime adult male.

5.3 DESCRIPTION OF INDIVIDUAL BURIALS

Individuals from the Quaker burial ground sample exhibited one or more forms of exoccipital, vertebral, or costal developmental defects. The following information is also summarized in tabular format in Appendix B-1.

KUT 1000

Thomas Barnard (KUT 1000), a prime adult male exhibited a Type II complete posterior arch bridge, symmetrically on both sides of the arch.

KUT 1005

The individual from this burial is a young male. A mild expression of cranial shift at the thoracolumbar border was noted. The transitional inferior articular facets were located on T11 instead of T12 (Plate 14). Additionally, the fifth thoracic vertebra exhibited centrum hypoplasia and the first sacral segment presented a cleft.

KUT 1019

Burial number 1019 is a prime adult male presenting an extra thoracic segment at the thoracolumbar border. The occipital condyles also exhibited evidence of incomplete dividing as did the left hypoglossal canal (Type II). The rim of the foramen magnum presented a medianly-positioned trace precondylar tubercle (Plate 5).

KUT 1022

John Barnard, a 74-75 year-old male possessed an extra thoracic segment at the thoracolumbar border (Plate 4). Furthermore, the sacrum of this individual exhibited an

anterior cleft between the first and second sacral segments (Plate 15) as well as hemimetamere hypoplasia of T4 (Plate 2). Additionally, the first cervical vertebra presented a Type I posterior arch bridge on the left (Plate 11).

KUT 1023

Burial number 1023 is prime adult female exhibiting the only example of Type II Klippel-Feil syndrome in the Quaker sample. In this case, C2 and C3 developed as mass of block-like tissue (Plate 3). The vertebrae were joined at the bodies, neural arches, and apophyseal facets. The sacrum of KUT 1023 also presented a sacral cleft between S1 and S2 (Plate 16).

KUT 1055

The individual associated with burial number 1055 is a mature female. The sacrum of this individual presented a cleft between the first and second sacral segments

KUT 1059

Burial number 1059 is a mature female exhibiting the only case of sacral hemimetamere hypoplasia within the KUT and St AUG collections. The right side of the first sacral segment was mildly underdeveloped (Plate 1).

KUT 1067

The individual from this burial is a mature female. The basilar portion of the occipital bone presented the only case of an incomplete transverse cleft (Plate 6). Additionally, the left hypoglossal canal of this individual was bipartite (Type I).

KUT 1073

Individual KUT 1073 is a juvenile of undetermined sex from the Quaker collection. KUT 1073 presented a Type II variety of bipartite hypoglossal canal on the left.

KUT 1074

Burial 1074 contained a mature male skeleton. The occipital condylar facets were bipartite (Type III)(Plate 7).

KUT 1077b

Individual KUT 1077b is a juvenile female presenting a medianly-positioned trace precondylar tubercle. This individual also exhibited a bipartite left hypoglossal canal (Type I).

KUT 1090

The individual from this burial is a prime adult male. This individuals' skeleton presented a case of Type I bipartite hypoglossal canal on the right.

KUT 1098

Individual KUT 1098 is a prime adult male showing a bipartite hypoglossal canal on the right.

KUT 1099

The individual from this burial is a young male presenting clefting of the neural arch of the twelfth thoracic vertebra (Plate 17) and centrum hypoplasia of T7. Additionally, this individual exhibited the only case of bilateral hypoplasia of both occipital condyles within both skeletal collections (Plate 12).

KUT 1112

Individual KUT 1112 is prime adult male presenting clefting of the neural arch of the atlas (C1) and mild anterior centrum hypoplasia of the seventh cervical vertebra (Plate 18).

KUT 1135

Individual KUT 1135 is a prime adult female showing anterior centrum hypoplasia of T5. This individual also exhibited a complete expression of cranial shifting at the thoracolumbar vertebral border. There was an absence of costal facets for the twelfth ribs and there were transitional inferior articular facets on T11 instead of T12 (Plate 13). Additionally, this individual presented a case of Type II lateral arch bridging on the right.

KUT 1141

The skeleton found associated with burial KUT 1141 is a mature male presenting a medianly-positioned trace precondylar tubercle on the rim of the foramen magnum. Furthermore, an example of Type I bipartite hypoglossal canal was also recorded on the right

KUT 1142

Burial number 1142 contained the skeleton of a mature female showing Type III lateral arch bridging on both sides of the first cervical vertebra (Plate 10).

KUT 1145

Individual 1145 is a mature adult female showing incomplete division of both occipital condyles (Plate 8). Additionally, the sacrum of this individual presented clefting of the first sacral segment.

KUT 1154

The individual from this burial is a mature female exhibiting a variety of bipartite hypoglossal canal on the left side.

5.4 ST AUGUSTINE THE LESS

Although the cemetery includes individuals from saxon-norman times through the 19th century, for the following discussion, temporal trends will not be discussed. It was impossible to make comparisons between individuals from the different periods because small sample sizes prevented any comparisons or the use complex statistics such as t-tests. As a population sample, presence and frequency of defects for the St Augustine the Less sample from Bristol, England are described below.

5.4.1 NOTOCHORD AND NEURAL TUBE DEFECTS

No examples of notochord defects were recorded in the St Augustine the Less collection. Furthermore, no known cases of neural tube defects were found within the skeletons of the St Augustine the Less parishioners.

5.4.2 ERRORS IN THE DEVELOPMENT OF THE PARAXIAL MESODERM

Forty-two skeletons from the St Augustine the Less collection were analysed for the presence of errors in the development of the paraxial mesoderm (i.e., errors in segmentation, differentiation, and delay). Fifty-percent (N=42) of individuals manifested

these pathologies. Affected individuals typically presented only one type of error of the paraxial mesoderm. However, the number of defects exhibited on each skeleton varied from zero to three.

When the sex distribution for the presence of these developmental defects of the paraxial mesoderm was calculated, 44% (N=9) of females, 58% of males, and 29% (N=7) of individuals of undetermined sex exhibited these particular traits. However, no significant difference was calculated when the sexes were compared. Sixty-three percent (N=8) of young adult skeletons from the AUG collection exhibited a minimum of one error in the development of the paraxial mesoderm. Furthermore, 62% (N=13) of prime adults, 50% (N=14) of mature adults, and 20% (N=5) of adults of unknown age exhibited some form of developmental defect involving the paraxial mesoderm. However, no significant age difference was calculated.

5.4.2.1 Errors in Segmentation

Only two examples (2/42= 5%) of errors in segmentation were recorded within the skeletons of the St Augustine the Less church sample (male: 1/26= 4%, female: 1/9= 11%). No example of hemimetameric shift, block vertebrae, or irregular segmentation of ribs or apophyseal joints was recorded within this collection. However, two cases of numerical errors in segmentation were recorded at the thoracolumbar border. The first case of a transitional vertebra was recorded on the skeleton of prime adult male (AUG 60) from the 18th-19th centuries. The extra vertebral segment exhibited lumbar-like

characteristics including wide transverse processes and lumbar-like superior and inferior articular processes (Plate 19). The second case of numerical error in segmentation was recorded in the skeleton of a mature female from the medieval period (AUG 72). The extra thoracic segment was also found at the thoracolumbar border (Plate 20).

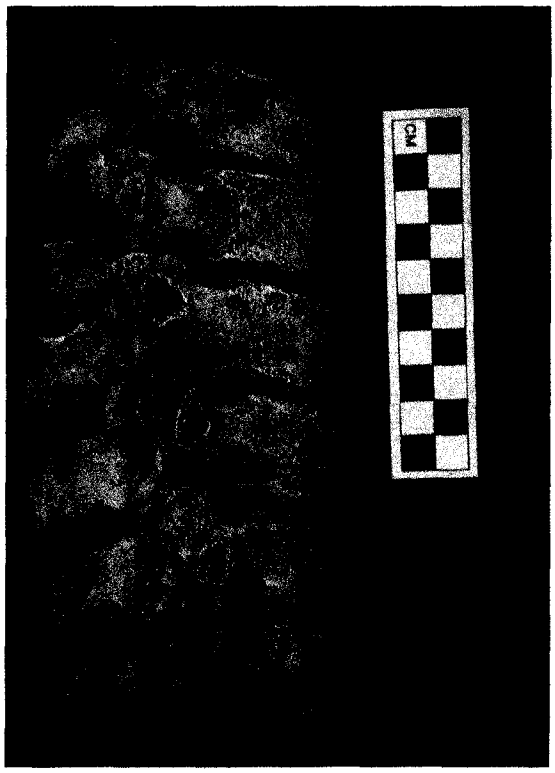

Plate 19: AUG 60 Photograph showing an extra lumbar vertebra (male, prime adult from the 18th-19th centuries).

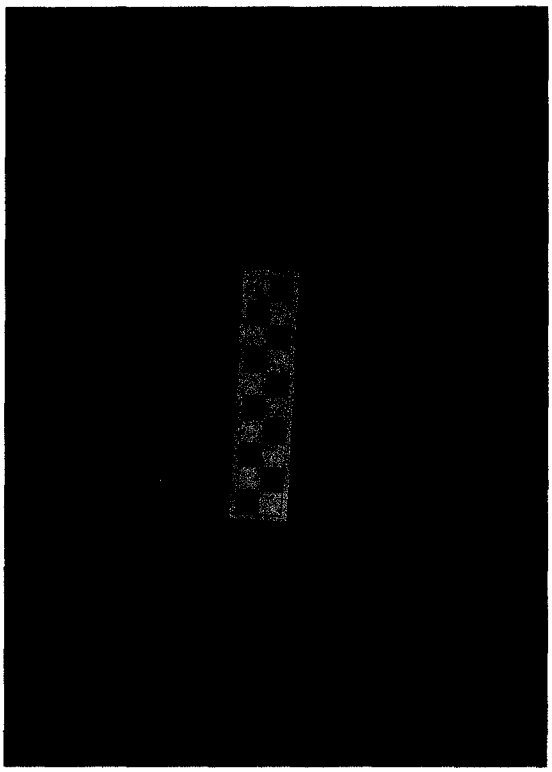

Plate 20: AUG 72 Photograph showing an extra thoracic vertebra (female, mature adult from the medieval historical period).

5.4.2.2 Failures in Differentiation (Border Shifts)

Evidence for transitional vertebrae resulting from shifting was recorded at all borders excepting the cervicothoracic. In total, 16 individuals (16/42 = 38%) recorded some form of border shifting at a minimum of one vertebral border. Shifting was recorded

in two of nine females (22%), twelve of 26 males (46%), and in two individuals of undetermined sex (2/7 = 29%). No difference in incidence was calculated when the sexes were compared. Affected individuals ranged in age from young to mature adult and were from the late saxon to as recent as the 18^{th}-19^{th} centuries. No age category presented more failures in differentiation compared to another. Cranial shifting (31%) was recorded more often than caudal shifting (17%). There was also evidence of shifting in both cranial and caudal directions in four males from the 18^{th}-19^{th} centuries (AUG 23, 60, 81, 84). More cases of shifting were noted at the occipitocervical border (21%, N=39) compared to any other in the AUG sample (cervicothoracic= 0%; thoracolumbar= 12%; lumbosacral= 5%; and sacrocaudal= 5%).

1. Occipitocervical border

No example of complete or incomplete cranial (occipital vertebra) or caudal shifting (occipitalization of the atlas) at the occipitocervical border were noted within the AUG sample. However, several mild expressions of shifting in cranial (6/42 = 14%) and caudal (5/42 = 12%) directions at this vertebral border were recognized.

Cranial shifting was represented by one example (1/42= 2%) of a medianly-positioned trace precondylar tubercle on the skeleton of a young male (1/26= 4%) from medieval times (AUG 18)(Plate 21). Other evidence of cranial shifting at the occipitocervical border was recorded in the form of bipartite hypoglossal canals. Five cases (5/42= 12%) of bipartite left hypoglossal canals were recorded in the skeletons

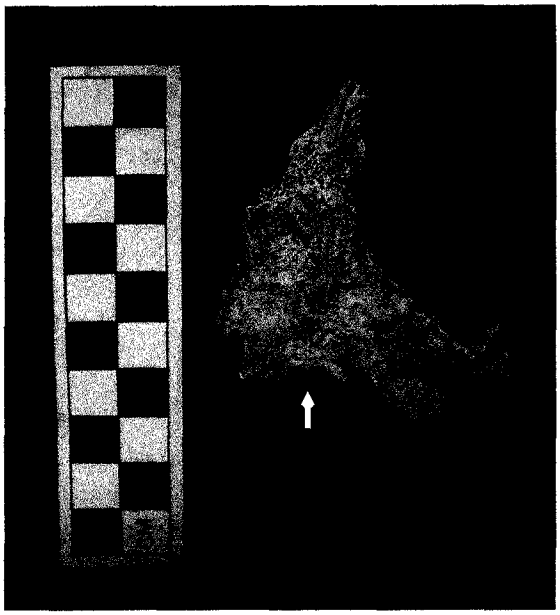

Plate 21: AUG 18 Photograph showing a medianly-positioned trace precondylar tubercle (young male, medieval period).

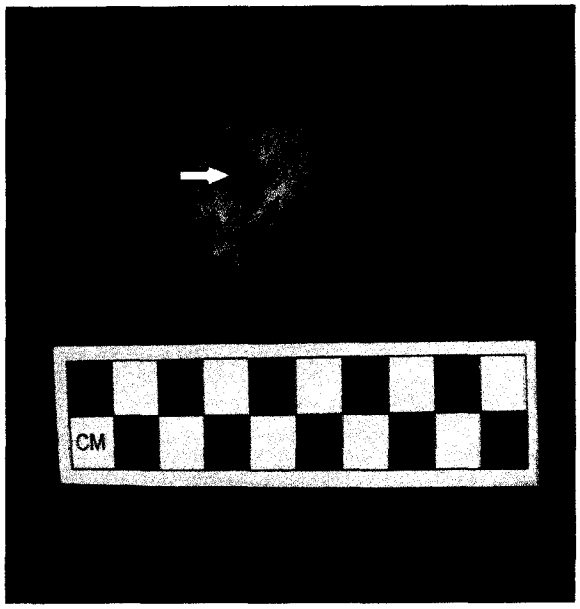

Plate 22: AUG 135 Photograph showing Type I bipartite hypoglossal canal on the left (undetermined sex, mature adult from the medieval period).

of three males (3/26= 12%) and two individuals of unknown sex (2/7= 29%)(Plate 22). Three varieties of this trait were recorded (Type I, III, IV) in individuals ranging in age from young to mature adult.

Caudal shifting was recorded in the St Augustine the Less collection. Five cases (5/42= 12%) of bridging of the first cervical vertebra were recorded. Four of the cases involved bridging of the posterior arch (Plate 23) and one the lateral arch (Plate 24). All individuals exhibiting these traits were males ranging in age from young to mature adult (5/26=19%). No other examples of caudal shifting at the occipitocervical border were recorded.

Plate 23: AUG 84 Photograph showing the Type III symmetrical posterior arch bridging of the first cervical vertebra of a mature male from the 18th-19th centuries.

Plate 24: AUG 60 Photograph showing the Type II bridging of the right lateral arch of the first cervical vertebra of an adult male from the 18th-19th centuries.

2. *Cervicothoracic border*

There was no evidence of cranial or caudal shifting at the cervicothoracic border in any of the skeletons from the St Augustine the Less church sample.

3. *Thoracolumbar border*

Nineteen-percent of male skeletons (5/26= 19%) within the AUG sample presented mild expressions of cranial shifting at the thoracolumbar border, Affected individuals ranged in age from young to mature adult exhibiting transitional inferior articular facets on T11 instead of T12 (Plate 25).

Plate 25: AUG 130 Photograph showing transitional facets on T11 instead of T12 on the vertebral column of a prime adult male from the medieval period.

Though no example of shifting at the thoracolumbar border was recorded in female skeletons, no significant difference in incidence between the sexes was found. Furthermore, no example of shifting in a caudal direction was observed.

4. Lumbosacral border

At the lumbosacral border, evidence of incomplete cranial shifting was recorded on two skeletons (2/42= 5%). The first case involved the fifth lumbar vertebra, the sacrum, and the ilium of a prime adult female from the 18th-19th centuries (AUG 24)(Plate 26).

The fifth lumbar vertebra of this individual exhibited a wide right transverse process articulating with both the sacrum (Plate 26a) and the ilium (Plate 26b).

Plate 26: AUG 24 Photograph showing a) wide alalike right transverse process of L5 articulating with the sacrum and b) articular facet on the ilium for L5 (prime adult female from the 18th-19th centuries).

The second case involved only the L5 and sacrum of a prime adult male from the 18th-19th centuries (AUG 60). The left transverse process of this individuals' fifth lumbar vertebra is wide and alalike and articulates with the sacrum. No examples of caudal shifting at the lumbosacral border were noted.

5. Sacrocaudal border

Two cases of shifting at the sacrocaudal border were recorded in the AUG skeletal

sample. Two instances (2/42= 5%) of caudal shifting (sacralization of the coccyx) were recorded in a prime adult male (1/26= 4%) and a mature female skeleton (1/9= 11%) from the medieval and post-medieval historical periods respectively. In both cases, there was complete incorporation of the first caudal segment into the sacrum (Plate 27).

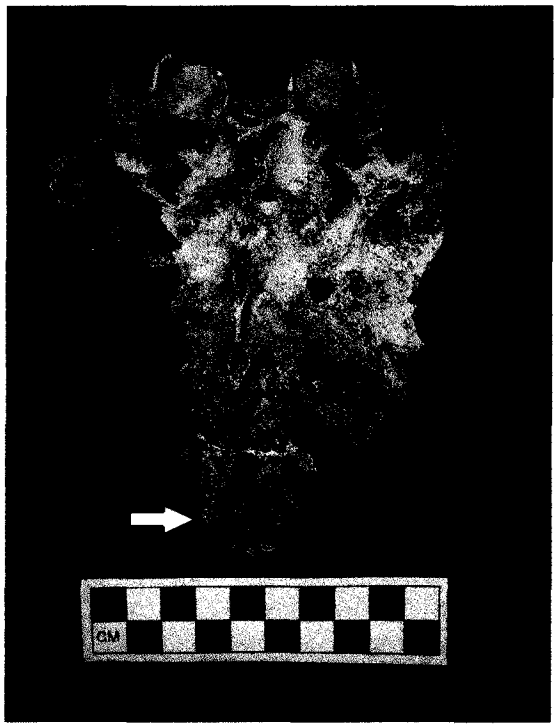

Plate 27: AUG 78 Photograph showing the complete sacralization of the first caudal segment of a mature female skeleton from the medieval period.

5.4.2.3 Developmental Delay of Structures

Developmental delay of the vertebral elements was recognized in six individuals from the St Augustine the Less sample (6/42 = 14%). Four cases (4/26= 15%) were recorded on male skeletons ranging in age from young to prime adult. The skeletons of

two prime adult females also showed evidence of developmental delay (2/9 = 22%). Clefting of the sacral neural arch was recorded in five individuals (three males, two females)(Plate 28). Furthermore, the skeleton of an adult male from the 18th-19th centuries . This individual exhibited anterior centrum hypoplasia of the first thoracic vertebra with an anterior/posterior vertebral body ratio of 1.3 (Plate 29).

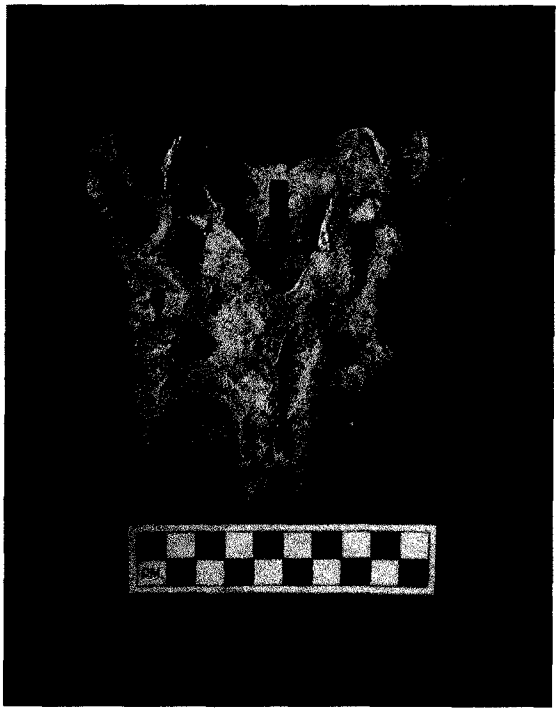

Plate 28: AUG 73 Photograph showing the sacral cleft neural arch of a young male from the medieval historical period.

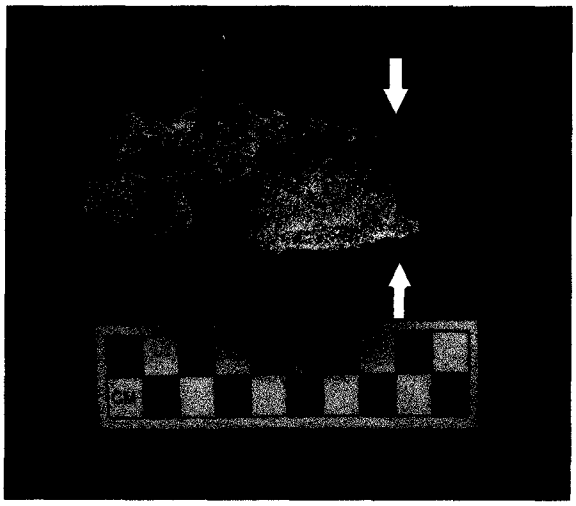

Plate 29: AUG 35 Photograph showing the anterior centrum hypoplasia of T1 of a prime adult male from the medieval period.

5.5 DESCRIPTION OF INDIVIDUAL BURIALS

Individuals from the St Augustine the Less church sample exhibiting single to multiple examples of exoccipital, vertebral, or costal developmental defects. The

following information is also summarized in tabular format in Appendix B-2.

AUG 18

Burial number 18 from the St Augustine the Less church is associated with a young male from the medieval historical period. While analysing the basilar portion of this individuals' occipital bone, a trace, medianly-positioned precondylar tubercle was observed flanking the anterior rim of the foramen magnum (Plate 21).

AUG 20

The individual from this burial is a mature male from the post-medieval historical period. The skeleton of this individual presented a variety of bipartite hypoglossal canal (Type III) on the left.

AUG 23

Individual AUG 23 is an adult male from the 18th-19th centuries showing bipartite left hypoglossal canal. Additionally, the skeleton of this individual presented Type II posterior bridging of the atlas on the left, and Type II bridging on the right. The sacrum of AUG 23 also exhibited clefting of the neural arch.

AUG 24

Burial AUG 24 is a prime adult female from the 18th-19th centuries. Cranial shifting was recorded at the lumbosacral border (Plate 26). The fifth lumbar vertebra possessed a wide right transverse process articulating with the sacrum. Furthermore, the ilium of this individual also exhibited articular facets for the fifth lumbar vertebra. The sacrum of AUG

24 also presented a sacral cleft at the S1-S2 junction.

AUG 35

The individual from this burial is a prime adult male from the medieval historical period. AUG 35 experienced developmental delay (centrum hypoplasia) of the first thoracic segment (Plate 29). The affected vertebra presented an anterior/posterior ratio of 1.3.

AUG 50

Burial number 50 contained the remains of a mature male skeleton from the 18^{th}-19^{th} centuries. The left hypoglossal canal presented a Type I variety of bipartite hypoglossal canal.

AUG 60

Individual AUG 60 is a prime adult male from the 18^{th}-19^{th} centuries. AUG 60 presented right lateral bridging of the first cervical vertebra (Plate 24). This individual also possessed an extra lumbar vertebra at the thoracolumbar border (Plate 19). Furthermore, cranial shifting at the lumbosacral border was noted.

AUG 65

The individual associated within this burial was a young male from the post-medieval historical period. A mild expression of cranial shift at the thoracolumbar border was discovered during the skeletal analysis of this individual.

AUG 72

Burial 72 contained the remains of a mature female from the medieval period possessing an extra vertebral segment at the thoracolumbar border (T13)(Plate 20).

AUG 73

Burial number 73 contained the remains of a young male from the medieval historical period. The sacrum of AUG 73 showed a developmental cleft between the first and second sacral segments (Plate 28).

AUG 78

The skeleton associated with this burial is a mature female showing caudal shifting at the sacrocaudal border (sacralization of the first caudal segment)(Plate 27).

AUG 81

Individual AUG 81 is a young male from medieval times. The left hypoglossal canal of this individual was bipartite (Type IV). Furthermore, during the analysis of the skeletal remains of AUG 81, a posterior bridge (Type II) was observed on the left side of the posterior arch of the first cervical vertebra.

AUG 82

Burial 82 is associated with the remains of a prime adult male from late saxon times. Cranial shifting at the thoracolumbar border was recorded during the skeletal assessment of this individual.

AUG 83

The skeleton found associated with burial AUG 83 is a prime adult male from the post-medieval historical period. This male presented caudal shifting at the sacrocaudal border (sacralization of the first caudal segment).

AUG 84

This individual is a mature male from the 18th-19th centuries. AUG 84 showed symmetrical posterior arch bridging of C1 (Type III)(Plate 23). This individual also exhibited cranial shifting at the thoracolumbar border (transitional facets on T11 instead of T12).

AUG 96

Burial 96 contained the remains of a young male from the medieval historical period. A cleft was observed on the sacrum of this individual.

AUG 103

The skeleton found associated with burial 103 is a mature male from late saxon times. A mild expression of cranial shifting at the thoracolumbar border was recorded during the skeletal analysis of this individual.

AUG 117

Burial 117 contained the remains of a prime adult female from the post-medieval historical period. The sacrum of this female presented a cleft.

AUG 124

AUG 124 is a prime adult male from the post-medieval historical period. This individual presented a Type III posterior bridge on the left side of the arch of the atlas.

AUG 130

Individual AUG 130 is a prime adult male from medieval times. A mild expression of cranial shifting was recorded at the thoracolumbar border (Plate 25).

AUG 135

Burial 135 contained the remains of a mature adult of undetermined sex from the medieval historical period. The left hypoglossal canal was bipartite (Type I)(Plate 22).

5.6 INCIDENCE OF DEVELOPMENTAL DEFECTS IN THE QUAKER BURIAL GROUND AND ST AUGUSTINE THE LESS SKELETAL SAMPLES

Skeletons from the Quaker burial ground presented more developmental defects absolutely compared to the skeletons from the St Augustine the Less collection. Skeletons from the Quaker collection presented 31% more defects compared to the skeletons from the St Augustine the Less (AUG= .67; KUT .98). However, this difference in average defect incidence was not significant. When sex and age distributions were factored in along with average number of defects exhibited per individual, no significant differences were calculated between both collections. However, as previously stated, because sample sizes were low, the statistical tests used may not have had the statistical power to detect existing differences.

5.6.1 NOTOCHORD AND NEURAL TUBE DEFECTS

The skeletons from both the Quaker burial ground and St Augustine the Less church suffered no notochord or neural tube defects.

5.6.2 ERRORS IN THE DEVELOPMENT OF THE PARAXIAL MESODERM

Errors in the development of the paraxial mesoderm were by far the most common defects recorded within both collections (AUG=50%; KUT=51%). No significant difference in incidence of errors in the development of the paraxial mesoderm was calculated between both collections. When the sex and age distributions of the skeletons presenting these defects were compared between collections, no significant differences were calculated.

Errors in segmentation. Errors in segmentation were recorded more frequently within the remains of those buried in the Quaker burial ground (12%) compared to the St Augustine the Less church (5%). Because of small samples sizes, it is unknown whether this difference was statistically significant. Extra vertebral segments were the errors in segmentation most often recorded between both collections (AUG = 5%; KUT = 5%). These errors took place only at the thoracolumbar vertebral border.

Failures in differentiation. In both the AUG and KUT skeletal samples, developmental defects related to errors in the differentiation (border shifts) were most common (AUG=38%; KUT= 41%). Shifting in a cranial direction (AUG= 31%; KUT=46%) was recorded more often compared to caudal shifting (AUG=17%; KUT=13%). However, skeletons from the Quaker sample presented more cranial and caudal shifts compared to individuals from the St Augustine the Less sample. This

difference in mean number of shifts between both collections was not significant.

With regards to location of shift, more shifting was recorded at the occipitocervical followed by the thoracolumbar border in both skeletal collections. No significant differences in shifting patterns were recorded following the skeletal analysis of both collections. In other words, there were no differences in the number of cases of defects recorded at each vertebral border between the collections. With respect to age distribution, no differences in mean number of shifts at particular borders were calculated between age categories.

Developmental delay of elements. Developmental delay of the vertebral elements was recognized in 14% (N=42) of the AUG collection and 21% (N=39) of the KUT skeletons. No differences between the collections were found with regards to sex and age predilections of these developmental traits.

In conclusion, the data indicates the presence of developmental defects in both samples. While some categories of defects are not represented, others are present more consistently. These differences characterize the developmental package exhibited by each collection. The results from the data, including differences in incidence between both collections, can now be used to discuss the implications of the findings of this research.

CHAPTER 6: DISCUSSION

Preliminary studies involving both the Quaker and St Augustine the Less skeletal collections have already been carried out prior to this study (e.g., Start and Kirk, 1998 and O'Connell, 1999). However, any additional investigation involving either collection could expand the information concerning the nature of the remains. The original purpose of this study was to examine the skeletal material recovered from the Quaker and St Augustine the Less collections for the presence of developmental defects and to relate defect frequencies to social and cultural elements. In the following discussion, theoretical and methodological considerations will be presented as well as a paleopathological interpretation of the data in light of these considerations.

6.1 LIMITATIONS OF THE DATA

It is widely recognized that there are several constraints when using a skeletal sample to understand the population from which it is drawn. One must consider the major limitations of archaeological information such as missing data resulting from differential preservation, small sample size, representivity, and time. In the best of all worlds, paleopathological research would deal only with complete skeletons and complete bones. However, in reality, paleopathologists are left to work with incomplete skeletons and fragmented remains.

Missing data. When considering burial processes, fetal and newborn remains are less likely to preserve compared to the skeletons of other age groups (Kirk, 1998:301). Therefore, it is possible that younger age groups from both samples may be under-represented. Consequently, more developmental defects may have been recorded on the skeletons of older individuals since there was a higher proportion of adult material recovered. This situation may have had an effect on defect frequencies. Furthermore, because of bone thickness, certain skeletal elements such as the tibia are more likely to survive burial compared to others such as the scapula. Therefore, more defects may have been recorded on more preservable skeletal elements since they are more likely to survive the process of interment.

As previously mentioned in Chapter 4, several skeletons were unavailable for study. This may explain why Bashford and Pollard (1998:163) noted extra vertebral segments in several of the Barnard family skeletons whereas during this particular research, only one Barnard family member presented a supernumerary vertebra. As mentioned in Chapter 4, missing data was not accounted for. Given the time constraints of this investigation and the range of developmental defects being studied, the most feasible treatment of the missing data was to treat it as though it had not been recovered. Because of these allowances, it is possible that the actual number of developmental defects presented by individuals from each collection may have been much lower or higher than calculated.

Sample size. Sample size was a general concern within this research. Original sample size of the combined collections was fairly large (N=132). However, because of poor preservation, only 61% of skeletons were analysed during this research (N=81). As previously discussed in Chapter 5, because of the small size of each of the analysed samples, statistical tests used may not have had the statistical power to detect significant differences. Therefore, calculated significance values may not be representative. Suggesting whether age or sex predilections existed was impossible with such small sample sizes since only two or three individuals presented certain traits. As a result, statistical treatment of the data was avoided because of the preliminary scope of this investigation and the problematic quality of the original data from both skeletal collections. Therefore in most cases, developmental defects were reported only as percentages or as proportions, allowing for small sample sizes.

Representivity. In skeletal analyses, one must also consider the nature of the burial population itself. Individuals buried within each cemetery may not have been representative of the population which they represent. Questions arise concerning which members of the society were buried within the church/burial ground. Perhaps only those individuals who could afford a church burial or those making the most contributions to the establishment were interred within the grounds surrounding the church. Therefore, one must consider how the skeletal collections do or do not approximate the population from which they are derived. These conditions may have affected conclusions regarding

pathology when relating back to the populations which the samples represent.

The non-randomness of the KUT sample must also be taken into consideration. As previously discussed, Bournemouth University kept only pathological cases as stipulated by the present-day Quaker community. This presents an issue of sample representivity, since only individuals bearing pathological conditions were retained. Furthermore, eighteenth-century historical documents reveal that non-Quakers were interred within the burial ground at London Road, Kingston-upon Thames. As previously mentioned in Chapter 3, burial registers record the interment of rich merchants and the spouses of members of the Society of Friends marrying outside the Quaker community (Bashford and Pollard, 1998:159,164). Therefore, the integrity of the Quaker cemetery as representing a genetic isolate remains questionable. Also worth mentioning, both the Quaker and St Augustine the Less cemeteries were not fully excavated. The perimeters of each cemetery clearly extend further beyond the limits of the excavated areas (Boore, 1985; Kirk, 1998). Therefore, both collections are samples of samples and must be treated as such.

Time. Within this research, one must also consider the time span of the burial grounds. The Quaker burial ground was used between 1663-1814 A.D., a period of 151 years (Bashford and Pollard, 1998:155). With more than 150 years of use of the burial ground at London Road, Kingston-upon Thames, there may have been changes in defect frequency and Quaker beliefs over time. With only six skeletons of known date of birth, investigating any potential temporal patterns was impossible. As previously mentioned in

Chapter 1, it was anticipated that Quaker skeletons would present a higher frequency of similar defects compared to the St Augustine the Less collection. However, if they were the first Quakers interred during the 1660's, there would not have been enough time for these defects to manifest since Quakerism had just begun in the mid-17th century (Stock, 1998:129). This is especially important since 80% of the total recorded burials occurred in the first 75 years of use of the cemetery (Start and Kirk, 1998:170).

The St Augustine the Less cemetery was used for more than 700 years. As previously mentioned, burials from this collection have been divided into the saxo-norman period (c.11th-12th centuries) followed by the medieval (c.13th-15th centuries) and post-medieval historical periods (c.16th-17th centuries) to as recently as the nineteenth century (Boore, 1998:70). However, there were not enough individuals within each time period to come to any valid conclusions regarding temporal trends in defect development. Therefore, the notion of time could affect the validity of any calculations.

The following discussion of the data requires a consideration of its inherent biases where these conditions should be kept in mind.

6.2 A GENERALIZED OVERVIEW

In this particular research, the highest frequency of developmental anomalies in both collections was recorded from mature adult skeletons followed by prime and young adults. Most skeletons within both functional samples were greater than 18 years of age, possibly explaining the high incidence within these age categories. Again, this may be

explained in terms of poor preservation of smaller infant bones and the resulting incomplete excavation of the remains. Overall, the occurrence of these anomalies was evenly distributed between the older age categories. However, because the samples contained little fetal, neonatal, infant, or juvenile remains, the previous statement remains questionable. Attaching any significance to the small number of infant remains presenting defects in both samples is therefore not possible.

Furthermore, a map exists showing the location of each skeletal burial within the Quaker burial ground at London Road, Kingston-upon Thames. No map exists outlining the burials of members of the St Augustine the Less church. Location within a cemetery can be used to suggest possible genetic relationships between individuals since burials are usually organized in family plots. However, with respect to burial style, Quakers were sometimes buried near their relations, but more frequently not (Stock, 1996). Therefore, in this case, proximity of graves cannot be used to suggest genetic relationships between those interred within the Quaker burial ground. Only the Barnard family vault can be used since names and genetic relationships are known.

As previously mentioned, several traits were infrequent enough to preclude statistical treatment of the data. Nevertheless, individuals buried in the Quaker burial ground were somewhat more likely to exhibit developmental conditions than those of the St Augustine the Less church. On average, Quaker skeletons presented more defects than the parishioners of the St Augustine the Less church. These results agree with the original hypothesis in supposing that since members of the Society of Friends were encouraged to

marry within the group, Quaker skeletons would therefore manifest more developmental disorders compared to those of St Augustine the Less church (Start and Kirk, 1998:171). However, this difference in defect incidence may be explained in terms of the representivity of the Quaker sample and not the result of an isolated gene pool. Since only pathological Quaker skeletons were kept, there may be a higher frequency of developmental defects in this sample. Regardless of incidence, one would expect more of a difference in the varieties of defects noted between both collections. Again, in compliance with the original hypothesis, one would expect a greater variety of defects on the skeletons of the St Augustine the Less parishioners since the sample includes individuals from diverse genetic backgrounds. However, contrary to the original hypothesis, individuals from both collections exhibited similar types of defects as though they originated from the same population (Figure 6.1).

For the most part, defects recorded in both collections were minor, where the paraxial mesoderm was usually affected and less common were neural tube and notochord defects (Figure 6.1). Few errors in segmentation such as block vertebrae and numerical errors were discovered on the skeletons of both samples. Failures in differentiation were the most common disturbances of the paraxial mesoderm noted in both collections. A trend toward cranial shifting at most borders was noted. Minor shifts were recorded most often at the occipitocervical followed by the thoracolumbar border in both excavated samples (Figure 6.1).

Table 6.1 Incidence of defects noted within the Quaker and St Augustine the Less skeletal samples.

		St Augustine the Less (incidence %) N=42	Quaker burial ground (incidence %) N=39
NOTOCHORD DEFECTS		0	0
NEURAL TUBE DEFECTS		0	0
PARAXIAL MESODERM CONDITIONS		50	51
I) Errors in Segmentation		5	12
II) Errors in Differentiation		38	41
Occipitocervical	cranial	14	33
	caudal	12	5
Cervicothoracic	cranial	0	0
	caudal	0	0
Thoracolumbar	cranial	12	5
	caudal	0	0
Lumbosacral	cranial	5	0
	caudal	0	3
Sacrocaudal	cranial	0	0
	caudal	5	0
III) Developmental Delay		14	21

At the occipitocervical border, similar errors in differentiation were noted such as precondylar tubercles, bipartite hypoglossal canals, and atlas arch bridging. However, individuals from both collections did suffer from dissimilar defects such as basilar clefts and hypoplasia of the occipital condyles, owing perhaps to an early genetic separation between both populations. No case of either cranial or caudal shifting was observed at the cervicothoracic border on the skeletons of individuals from both samples (Figure 6.1).

Furthermore, only evidence of mild cranial shifting at the thoracolumbar border was noted during the examination of both collections. At the lumbosacral and sacrocaudal vertebral borders, differences in direction and location of shift were noted between both excavated samples (Figure 6.1). As for developmental delay, individuals from both samples exhibited clefting of the vertebrae and sacrum and anterior centrum hypoplasia. Individuals from both collections no doubt present a similar developmental defect package.

As discussed above, there are several potential reasons for this small difference in defect frequency between both collections. Many Kingston-upon Thames skeletons examined during this research may not have been Quakers. As previously noted, non-Quakers may have been interred within the burial ground at London Road, Kingston-upon Thames (Bashford and Pollard, 1998:159). Furthermore, the skeletons of those members examined may not have been part of the isolated gene pool long enough to manifest these genetically-linked defects. In other words, because the cemetery dates to the beginning of Quakerism, there may not have been enough genetic isolation to produce similar defects in the organizations' members. Perhaps individuals from both the Quaker and St Augustine the Less burial grounds originate from a similar gene pool where there had not been enough genetic isolation to produce a larger difference in defect frequency.

6.2.1 NOTOCHORD AND NEURAL TUBE CONDITIONS

While the cause of notochord defects remains uncertain, several etiologies have been proposed in the development of neural tube defects. Maternal deficiencies in

selenium, zinc, and folic acid are known to effect neural tube development (Barnes, 1994). Researchers have attributed certain neural tube defects such as sacral agenesis to both autosomal dominant and recessive mutant genes (Warkany, 1971). Teratogenic agents such as trypan blue (dye) and streptonigrin (highly toxic antibiotic) have been shown to invoke neural tube defects in laboratory animals (Warkany, 1971:924). Maternal diabetes is also known to lead to various forms of sacral agenesis.

A lack of notochord and neural tube defects in both collections may suggest that those interred within the Quaker and St Augustine the Less burial grounds may have suffered little dietary deficiencies, or diabetes, and were not subject to the harmful effects of certain teratogenic compounds (Warkany, 1971:924; Zimmerman and Lozzio, 1989:48). Selenium, zinc, and folic acid are essential for the growth and development of the skeletal system (Barnes, 1994). Individuals from both samples may have satisfied their dietary requirement of selenium since it is readily available in high quantities in meats, fish and grains. Furthermore, zinc is highly abundant in red and white meat and shellfish (Zimmerman and Lozzio, 1989:48). Folic acid (also known as folate) is found naturally in leafy greens and several fruits.

These commodities have been mentioned in the historical literature concerning goods entering the surrounding ports of England from the early middle ages until the 19th century (Walker, 1971; Vanes, 1977). A traditional Quaker diet would have consisted of little sugars and highly processed carbohydrates such as white flour (Start and Kirk, 1998:173). As a result, conditions such as diabetes may not have been as prevalent in this

society compared to that of the St Augustine the Less. However, as previously shown, this Quaker cemetery is not exactly a conformist one. Individuals may have deviated from the doctrines. Diet of the St Augustine the Less parishioners is unknown other than foodstuffs such as corn, fish, rice, and wheat listed on historical customs documents (Vanes, 1977). This suggests that the diet of pregnant women may have been sufficient in fulfilling the nutritional requirements of a developing fetus. In other words, an absence of neural tube and notchord defects suggests that Quakers buried within the site at Kingston-upon Thames led remarkably healthy lives. These findings agree with those of Start and Kirk (1998).

An adequate diet including the previously mentioned nutrients would have led to an overall absence of notochord or neural tube defects within both excavated samples. However, lack of incidence of both notochord and neural tube defects may also be explained in terms of lack of preservation and recovery of fetal and infant remains. Additional research is required to clarify possible genetic and/or environmental influences acting upon the skeleton, producing notochord and neural tube abnormalities.

6.2.2 CONDITIONS OF THE PARAXIAL MESODERM

6.2.2.1 Errors in Segmentation

Transmission of these defects is far from understood where both genetic and non-genetic environmental factors are known to play an important causal role. Therefore, one must discuss their incidence and implications separately. As shown in Chapter 5, few

errors in segmentation were recorded. However, cases of hemimetamere hypoplasia, block vertebrae, and supernumerary segments were noted within both the KUT and AUG skeletal samples. The presence of errors in segmentation in both skeletal samples suggests that individuals were somehow susceptible to these errors in development.

Two cases of hemimetamere hypoplasia were recorded in the Quaker collection. The first, on the skeleton of a Barnard family member (John Barnard: KUT 1022). This individual also exhibited a posterior arch bridge on C1, an extra thoracic vertebra, and evidence of mild cranial shifting at the lumbosacral border as an anterior cleft. It is unknown whether any of these traits are linked. The second case was discovered on the skeleton of a mature female (KUT 1059). The first sacral segment of this individual was underdeveloped on the right. The cause of this trait remains obscure and several authors have suggested hereditary factors while others support the possibility of a chromosomal anomaly (Warkany, 1971). No mention of this defect within the paleopathological literature could be found. Discussing the implications of this trait is difficult since its etiology is misunderstood and few cases have been reported in the literature. Much work remains to be done concerning the etiology of hemimetameric defects. Only with more research into the nature of these errors in segmentation will the importance of its presence and lack of incidence in the Quaker and St Augustine the Less collections be clear.

The only example of Klippel-Feil syndrome was discovered in the Quaker collection (KUT 1023). This individual presented a Type II vertebral block and clefting of the first sacral segment. This syndrome is usually associated with hemivertebrae, cervical

ribs, and occipitoatlantal fusion. However, none of these traits were noted. Because fusion of C2-C3 is the most common form of Klippel-Feil syndrome, its presence in this collection is not surprising (Barnes, 1994:237). Since only two vertebrae were involved, this individual probably did not suffer from a short neck and low posterior hairline. These symptoms are only seen in individuals with fusion of several vertebrae (Pizzutillo, 1989:259). Because Type II fusions are the less severe type of block, it is suggested that more severe forms (Type I, III) may have existed. Individuals presenting more severe varieties of Klippel-Feil syndrome usually suffer from other major defects and do not survive into adulthood (Barnes, 1994:240). There were no other cases of block vertebra or Klippel-Feil syndrome and whether other cases existed within both collections and were absent resulting from preservation remains unknown.

Klippel-Feil syndrome is known to follow a genetic path of inheritance. Anderson (1989) noted several cases of Type II Klippel-Feil syndrome in three infant burials from the Homol'ovi III, northern Arizona. The presence of this trait was used to suggest a genetic link among the three infants. This syndrome is usually painless and several agents such as alcohol have also been shown to induce these errors in segmentation in individuals with sensitive genetic backgrounds (Pizzutillo, 1989:263). It is likely that many disruptive agents such as alcohol and lead were present in the Quaker and Bristol communities from the mid-thirteenth century until the early eighteen hundreds. Wine, beer, and lead have been mentioned in the early historical documents concerning English trade (Walker, 1971; Vanes, 1977). Whatever the case, both collections show evidence for the development of

errors in segmentation.

Numerical errors were recorded more often than any other error in segmentation in both collections. Extra vertebral segments were recorded exclusively at the thoracolumbar border. Because several vertebral columns were incomplete, calculated frequencies for this trait are for the material examined, and not for the site sample as a whole. Little can be said regarding the exact nature of these defects. However, supernumerary segments are believed to follow familial lines of inheritance and evolutionary models have been proposed (Bornstein and Peterson, 1966). Bornstein and Peterson (1966) believe there to be a tendency in all populations toward an increase in vertebral number in males and a decrease in vertebral number in females. However, in the KUT and AUG skeletons, extra vertebrae were recorded for both male and females, where no missing segments were noted. These findings shed at least some doubt on Bornstein and Peterson's (1966) evolutionary explanation for numerical errors in segmentation.

The use of numerical errors in segmentation to determine the level of homogenization of a group is questionable. However, during the examination of ten vertebral columns from a small group of Proto-historic Modoc Indians from northern California, Bennett (1972) noted the presence of extra vertebral segments at the lumbosacral region with an incidence of 90%. In all cases but one, the sixth lumbar vertebra was incompletely sacralized. Several extra lumbar vertebrae also exhibited clefting of the neural arch. Bennett (1972:438) believed the high incidence of these traits to be attributed to high levels of inbreeding leading to a homogenization of the gene pool

over several generations. Because of the excellent state of preservation of the skeletons of the Quaker Barnard family, it was anticipated that supernumerary and missing vertebrae would be discovered. However, only one case of an extra vertebral segment was found in a Barnard family member (John Barnard: KUT 1022). This inhibited any further study of the familial nature of this trait.

It is tempting to try to establish a genetic link between the Quaker and St Augustine populations since extra vertebrae were recorded solely at the thoracolumbar border in both collections. Geographically, the Quakers and the parishioners of the St Augustine the Less church were separated by only a little over one hundred kilometres. Temporally, both burial grounds overlapped each other. However, culturally they did not share common values. In the literature, supernumerary vertebral segments are commonly found at the thoracolumbar border (Allbrook, 1955; Barnes, 1994:241). Therefore, it may be a mere coincidence that both collections present this trait where no cultural significance may exist. However, similar patterns of defects are suggestive of a common gene pool.

6.2.2.2 Failures in Differentiation (Border Shifts)

As previously stated, because of gene pool size, one would expect Quaker skeletons to exhibit similar border shifting patterns leading to the development of similar defects. As for the skeletons of the St Augustine the Less collection, one would expect an array of border defects resulting from shifting in both cranial and caudal directions. However, this was not so. Direction of the shift was similar at most borders in both

collections where little differences in defect patterns were recognized. Cranial shifting was recorded more often than caudal shifting in the material examined from both the AUG and KUT samples. The greatest amount of shifting was recorded at the occipitocervical border followed by the thoracolumbar region in both skeletal samples. Quaker individuals exhibited shifting at all borders excepting the cervicothoracic and sacrocaudal whereas the parishioners of St Augustine the Less church experienced shifting at all borders excluding the cervicothoracic.

Kühne (1932) showed a tendency for shifting to occur in the same direction within genetically related individuals (from Allbrook, 1955:499). Because the Quaker and St Augustine collections show similar shifting patterns, it seems probable that they may have originated from the same gene pool. Kühne also believed caudal shifts to be controlled by a recessive gene and cranial shifts by a Mendelian dominant gene (from Allbrook, 1955:499). However, shifting was recorded in both directions in the same individual within this research on AUG 23, 60, 81, 84, and KUT 1135 and elsewhere within the literature (e.g., Shore 1930; Searl 1954; Allbrook 1955; Bornstein and Peterson, 1966; Schmorl and Junghanns 1971; Merbs 1974). Therefore, it seems likely that an array of factors may influence direction of shift in an individual. However, if these genes are located on different alleles, shifting in both directions within the same individual is possible.

Recent evidence suggests that a group of genes referred to as HOX (homeobox) genes are responsible for shifts at vertebral borders (Saegusa et al., 1996; Innis, 1997).

HOX genes are believed to control the development and subsequent differentiation of somites. These genes direct the future identity of the somites. Problems with homeobox proteins lead to shifting in individual vertebral characteristics (Martínez-Frías, 1994; Martínez-Frías, 1997a; Martínez-Frías, 1997b). Environmental factors can influence the chain of events to produce failures in differentiation. Usher and Christensen (2000) attributed the border shifts noted in the skeleton of a young Danish woman from the 12th century A.D. to homeobox genes. Therefore, combinations of genetic abnormalities and environmental disturbances are likely to blame for the many cases of failures in differentiation noted within the KUT and AUG collections.

Research has shown that the vertebral columns of New World aborigines seem to show a strong tendency toward caudal shifting. For example, Bornstein and Peterson (1966) observed a high frequency of caudal shifting in the skeletons of the Aleut-Koniag-Plains Indian collection. Similarly, Merbs (1984) noted a strong tendency toward caudal shifting in the vertebral columns of the Sadlermiut Eskimos from the Northwest Territories and the Northwest Coast collection including the Haida, Kwakiutl, and Nootka. Furthermore, in a study of 82 Maritime Archaic Indian skeletons from Port au Choix, Newfoundland (4400 - 3300 B.P.), a definite pattern of caudal shifting was noted (Pitre, 2003:47). It seems plausible that European and Aboriginal columns may exhibit shifting in opposite directions (i.e., cranial versus caudal). Unfortunately, little mention of shifting has been made when referring to European columns. Usher and Christensen (2000) fail to note the direction of shift in the female skeleton from Denmark. However, they do

mention some evidence of cranial shifting at the thoracolumbar border, a border where shifting did occur regularly in both the Quaker and St Augustine skeletons.

With respect to specific borders, more shifting was recorded at the less-stable occipitocervical border compared to any other in both collections. A similar trend was noted in Barnes' population study of the Puye of New Mexico (Barnes, 1994). The presence of several milder manifestations of an occipital vertebra suggests that individuals from both populations may have suffered from the more extreme expression. Evidence for more extreme defects is lacking. In both collections, several milder manifestations were recorded such as precondylar tubercles, bipartite occipital condylar facets, transverse basilar clefts, and bipartite hypoglossal canals. The specific etiologies of many of these traits are unknown. However, as with all failures in differentiation, several genetic and environmental factors have been proposed. More research is required to pinpoint the exact nature of these defects to discuss their significance. Furthermore, because few examples of these traits were noted, it is difficult to discuss them in relation to the populations in question.

Few cases of cranial or caudal shifting at the thoracolumbar border have been mentioned in the literature to date (Barnes, 1994). Perhaps because the inferior articular facets are a region rarely examined, mild evidence of shifting may go unnoticed. However, Merbs (1974) found these shifts at an incidence rate of 2.8% in the Sadlermuit and 7.1% in the Northwest Coast Indians. Within the Quaker and St Augustine the Less collections, several cases of mild and complete shifting were noted. Several individuals presented a

mild shift resulting in transitional inferior articular facets on T11 instead of T12 and the complete manifestation of lack of development of the twelfth thoracic ribs. These characteristics were recorded at an incidence rate of 5% in the Quakers and 12% in the St Augustine the Less collection. Because the mild form was prevalent in both the KUT and AUG samples, it is possible that individuals from both populations may have suffered from the more extreme condition of lack of development of the twelfth thoracic ribs.

At the lumbosacral border, evidence of both minor and major manifestations of shifting were noted on the skeletons of both Quakers and St Augustine the Less parishioners. Cranial shifting was found on the skeletons of the parishioners of the St Augustine the Less church whereas caudal shifts were noted on Quaker skeletons. The collections differed in this respect. Reasons for this difference in direction of shift are manifold where any explanation is as good as another. Difference in shift at this border may reflect genetic separation between both collections. Furthermore, only one case of caudal shifting was recorded in the Quaker collection, making any generalizations concerning direction of shift difficult. It is possible that this is an anomaly where all other Quaker sacra would have presented cranial instead of caudal shifting. Therefore, calculated incidence rates are for the excavated sample and not the populations from which they are drawn.

Shifting at the sacrocaudal border was observed in the skeletons of the parishioners of the St Augustine the Less church. The collections also differed in this respect. Two cases of sacralization of the coccyx were recorded on the skeletons of a male and female.

Again, the cause of this defect is misunderstood. Various etiologies have been proposed including genetic and environmental disturbances. Individuals exhibiting this trait would have suffered no clinical significance.

6.2.2.3 Developmental Delay of Structures

Failure of a structure to reach its critical size during blastemal development results in the chondrification and subsequent ossification of parts reduced in size (i.e., hypoplastic) or a complete failure of the structure to develop (i.e., aplasia)(Barnes, 1994:117). Within this analysis, several cases of developmental delay were recorded at an incidence rate of 21% in the Quaker and 14% in the St Augustine the Less skeletons. Skeletons from both collections presented clefting of the vertebral and sacral arches and few cases of centrum hypoplasia.

If clefting is a result of nutritional deficiencies as with spina bifida, a higher incidence among individuals from both collections may suggest that individuals were unable to meet certain nutritional requirements. However, this generalization remains highly hypothetical since only one case of a neural tube defect was discovered. This is even more convincing evidence that genetic factors may be involved in the transmission of these developmental traits. More studies are required to determine the defect's cause, which may then be used to suggest possible genetic and/or environmental influences.

Several potential explanations as to why few differences in these traits were found between both collections have been presented. One explanation is that both collections

were once part of the same gene pool and that time would have worked to increase the homogeneity of defects. Tied in with this explanation, the Quaker organization would have been newly formed, explaining why individuals from Kingston-upon Thames failed to exhibit the characteristics of an isolated gene pool. Once several generations had past, time may have worked to add variability between the collections and increase the homogeneity within the Quaker group. However, individuals buried in the Quaker cemetery at London Road Kingston-upon Thames were known to practice loose patterns of marriage where they may have brought others from other groups. This would have a similar effect of diminishing differences in defect variability between the collections over time. Overall however, there is a trend for Quakers and St Augustine the Less members to possess a similar developmental package of defects.

CHAPTER 7: CONCLUSIONS AND FUTURE CONSIDERATIONS

7.1 INTRODUCTION

This study has been concerned with the use of metric and non-metric observations in determining the presence and incidence of developmental anomalies within the vertebral columns, ribs, and exoccipitals of a group of 39 Quakers from Kingston-upon Thames and 42 members of the St Augustine the Less church, Bristol. The data from this analysis suggests a definite pattern of developmental defects in the aforementioned skeletal regions within both skeletal populations. The compilation and use of Barnes' (1994) morphogenetic framework eased the identification and classification of these anomalies.

The first goal of this research was to identify and evaluate the presence of development pathology on the skeletons of the Quaker and St Augustine the Less burial ground samples. Through the examination of the vertebral columns, ribs, and exoccipitals, an inventory was created and the location of each defect noted. The inventory enabled the calculation of defect frequencies, so that distribution, location, and frequency could be assessed. By calculating the number of individuals exhibiting defects and comparing them to the number of individuals within each collection, frequencies were provided allowing for comparisons between both skeletal samples.

The second goal of this research was to attempt to infer aspects of life from both collections through the examination of defect patterns. An effort was made to place each individual within the model of their local population. As a result, clues concerning the genetic and social structure of the Quakers and St Augustine the Less parishioners were

considered. From combinations of skeletal and historical evidence, a general picture was created concerning both samples. Little variation was found in the incidence of defects between both collections. This evidence was used to suggest that both groups originated from a similar gene pool where differences in defect patterns may be attributed to genetic distance. Furthermore, it was suggested that this particular Quaker population may not have been as genetically isolated as previously conceived. Skeletal evidence coupled with historical documents concerning the non-conformist nature of this particular Quaker group suggests that members of the Society of Friends may not have always selected marriage partners from within the group. This would have worked toward decreasing the homogeneity within the Quaker group, making their developmental package similar to that of the St Augustine the Less church. Furthermore, because of a general absence of nutritionally-derived traits, it was suggested that individuals from both archaeological samples probably led reasonably healthy lives.

Because of sample size, it was difficult to use the developmental patterns of the defects to suggest any differences in incidence between the sexes and in the case of St Augustine the Less, to suggest any temporal trends in defect development. Furthermore, the Barnard family vault failed to yield information concerning the familial nature of certain traits. Skeletal evidence thus suggests that both populations may have been culturally and environmentally-equipped to overcome these insults that develop during early childhood. In other words, their environment may have provided enough nutrients to provide for the developing fetus *in utero*. However several confounding factors such as missing data,

time, sample size and representivity may have had an affect on defect frequencies within this research.

Overall, the presence of several developmental defects within the individuals of both the Quaker and St Augustine the Less collections suggests that the populations were somewhat susceptible to genetic and/or environmental influences. Furthermore, the very presence of milder expressions of these defects on several adult skeletons suggests that more severe forms (i.e., spina bifida, aplasia of sacrum) probably existed within both populations. As previously stated, these defects may not have been found within either skeletal population because the conditions usually manifest *in utero.* Individuals presenting these traits usually do not survive until adulthood and few fetal and infant remains were recovered.

A definite pattern of developmental defects was noted during this research. Most of the developmental defects detected in the Quaker and St Augustine skeletal collections were minor. The majority of defects consisted of disturbances in the development of paraxial mesoderm of the vertebral column. Border shifting and developmental delay of vertebral elements (clefting of the sacrum and select vertebrae) were the most common paraxial mesoderm defects. Less common were errors in segmentation such as block vertebrae and numerical errors. Notochord defects and rib abnormalities were absent. Some defects were sporadic, recorded in only one or a few skeletons (e.g., transverse basilar cleft) while a tendency for certain defects to occur more frequently than others was apparent (i.e., cranial shifting at occipitocervical and thoracolumbar borders).

7.2 FUTURE CONSIDERATIONS

This research has contributed to the limited knowledge concerning the various expressions of the more subtle defects and their development. This study is open-ended so as developments are made, they may be easily incorporated into this framework. Indeed, all aspects of the process of defect formation require more special attention. More exhaustive field research is required to strengthen the relationship between other variables affecting skeletal morphogenesis to shed light on the etiology of these anomalous conditions. Additional research is required concerning the genetic and/or environmental influences on the development of the skeleton so that in the future, this study may be reevaluated where more information concerning the lifestyles of those buried within both cemeteries be revealed. Only once the etiology of each trait has been uncovered, can these defects be used with confidence in osteological analyses involving prehistoric and historic populations. However, the complex interactions between environment and genetics continue to hinder analyses leading to precise genetic explanations.

It is important for paleopathologists to become familiar with the various expressions of these defects in order to accurately assess the skeletal health of an individual. This research is important because it addresses the many varieties of defects not generally mentioned within the paleopathological literature. Furthermore, agreeing upon the most appropriate descriptive means of categorizing these defects is also necessary. Only then will complex comparisons be possible between skeletal collections. However, the study and understanding of these traits is only in its infancy. This study

stems from work carried out by Barnes (1994) in providing information to begin to understand genetic distance between populations and to attempt to determine cultural and environmental influences acting upon the skeleton. This investigation into the nature of developmental defects of the vertebral column, ribs, and exoccipitals represents ongoing research where advances in technology and research will no doubt shed light on their significance and potential to be used within osteological studies. Additional disturbances will no doubt be discovered where the nature of others revealed.

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APPENDIX A

Specimen #	Sex: M F	Age:
Date examined (mm/dd/yyyy):		
NOTOCHORD DEFECTS		
Coronal cleft centrum 0= absent		
Saggital cleft centrum 0= absent 1= narrow bifurcation 2= complete cleft 3= bony connector		
Mesenchymal diastematomylia 0= absent		
NEURAL TUBE DEFECTS		
0= absent 1= **Meningomylocele** 2= **Meningocele with spina bifida cystica** 3= **Meningocele with spina bifida occulta**		
Sacral agenesis 0= absent 1= complete agenesis 2= partial agenesis		
PARAXIAL MESODERM DEFECTS		
A. Segmentation errors		
Hemimetamere shifts 0= absent 1= solitary 2= multiple (c=contralateral; un=unilateral; bi=bilateral)		
Hemimetamere hypoplasia/aplasia 0= absent 1= hypoplasia 2= aplasia		

Block vertebra(e)/Klippel-Feil Syndrome
0= absent
1= Type I
2= Type II
3= Type III
4= probable but undetermined

Rib abnormalities
0= absent
1= combined/adjacent/fused
2= bridging
3= wide
4= flared
5= bifurcated
6= spurs

Neural arch and apophyseal joint failure
0= absent
1= present
2= undetermined

LSF= left superior articular facet
RSF= right superior articular facet
LIF= left inferior articular facet
RIF= right inferior articular facet

Supernumerary/missing vertebra(e)
0= absent
1= supernumerary
2= reduction
3= missing segments/undeterminable

C.__ + T.__ + L.__ + S.__ + Co.__ = __

B. Cranial/caudal shifts

Occipitocervical border

a. cranial shift:
0 = absent
1 = complete occipital vertebrae
2 = incomplete occipital vertebrae
mild expressions:
3 = precondylar tubercle (paired, right, left, median);
(trace, small, medium, large); (presence or absence of articular facet)
4 = transverse bar cleft (incomplete, complete)
5 = bipartite occipital condylar facets (incomplete = lateral or bilateral)(complete)
6 = bipartite hypoglossal canal (Type I, II, III, IV)

odontoid displacements:
7 = os odontoidem
8 = ossiculum terminale;
9 = agenesis of dens
10 = agenesis of apical segment
11= agenesis of odontoid

b. caudal shift:
1 = complete assimilation
2 = incomplete assimilation
mild expressions:
3 = paracondylar processes (medial/lateral/accessory);(small, medium,large);
(no articular surface, small articular surface, medium articular surface)
4 = epitransverse process (a=absent bridge; p=partial bridging;
b=bony bridge)(bi=bilateral; un=unilateral)
5 = hypoplasia of occipital condyles
6 = precondylar articulating facet

c. basilar impression
anterior-posterior diameter of :

foramen magnum_____mm

C1___mm	C5___mm
C2___mm	C6___mm
C3___mm	C7___mm
C4___mm	

0 = absent
1 = present
2 = undetermined

Cervicothoracic border
a. cranial shift: cervical ribs; (l/r)(la=lateral;bi=bilateral)
0 = absent
1 = class I (bony tubercle)
2 = class II (blunt 40-50mm projection)
3 = class III (rib extension without costal joint)
4 = class IV (complete with costal joint)
mild expression:
5 = T2 attaches to lateral edge of manubrium

b. caudal shift:
0 = absent
1 = rudimentary first thoracic rib (< than 30mm in length)
mild expression:
2 = T2 attaches to side of mesosternum

Thoracolumbar border
a. cranial shift
0 = absent
1 = complete expression (rudimentary T12 with slender tapered tip)
2 = mild expression (transitional facets at T11 rather than T12

b. caudal shift (lumbar ribs)
0 = absent
1 = complete expression (un=l/r;bi=bilateral)
2 = mild expression (transitional facets at L1 instead of T12)

Lumbosacral border
a. cranial shift
0 = absent
1 = complete sacralization
2 = incomplete expression

b. caudal shift
0 = absent
1 = complete lumbarization
2 = incomplete expression
3 = mild expression

Sacrocaudal border
a. cranial shift
0 = absent
1 = complete expression
2 = incomplete expression

b. caudal shift
0 = absent
1 = complete expression
2 = incomplete expression

C. Developmental delay

1. Neural Arch
0 = absent
1 = hypoplasia
2 = aplasia
3 = cleft
4 = bifurcation
un = unilateral (l/r);bi=bilateral
M = missing
D = damaged element

2. Centrum
0 = absent
1 = aplasia of centrum
2 = hypoplasia of the anterior portion of the centrum
3 = hypoplasia of the posterior portion of the centrum

Vertebral Body Measurements (mm)						
Measurement (mm)	Centrum Hypoplasia (mm)			Hemimetamere Hypoplasia		
	Anterior Measurement of Vertebral Body (mm)	**Posterior Measurement of Vertebral Body (mm)**	**Posterior/ Anterior Ratio (mm)**	**Left Lateral Measurement of Vertebral Body (mm)**	**Right Lateral Measurement of Vertebral Body (mm)**	**Lateral/Lateral Ratio (mm)**
T1						
T2						
T3						
T4						
T5						
T6						
T7						
T8						
T9						
T10						
T11						
T12						
T13						
L1						
L2						
L3						
L4						
L5						

APPENDIX B-1

Descriptions of individual burials from the **Quaker burial ground, Kingston-upon Thames** in relation to defects recorded.

	KUT 1000	KUT 1005	KUT 1019	KUT 1022	KUT 1023	KUT 1055	KUT 1059	KUT 1067	KUT 1073	KUT 1074	KUT 1077b	KUT 1090	KUT 1098	KUT 1099	KUT 1112
sacral agenesis															
hemimetamere hypoplasia				X			X								
block vertebrae					X										
supernumerary vertebrae			X	X											
precondylar tubercles			X								X				
bipartite/hypoplasia condylar facets			X							X				X	
transverse basilar cleft								X							
bipartite hypoglossal canal			X					X	X		X	X	X		
bridging of the atlas	X														
transitional facets on T11		X													
anterior cleft between S1&S2				X											
clefting		X			X	X								X	X
centrum hypoplasia		X												X	X

continued....

Descriptions of individual burials from the **Quaker burial ground, Kingston-upon Thames** in relation to defects recorded.

	KUT 1135	KUT 1141	KUT 1142	KUT 1145	KUT 1154
sacral agenesis					
hemimetamere hypoplasia					
block vertebrae					
supernumerary vertebrae					
precondylar tubercles		X			
bipartite/hypoplasia condylar facets				X	
transverse basilar cleft					
bipartite hypoglossal canal		X			X
bridging of the atlas	X		X		
transitional facets on T11	X				
anterior cleft between S1&S2					
clefting				X	
centrum hypoplasia	X				

APPENDIX B-2

Descriptions of individual burials from the **St Augustine the Less cemetery, Bristol** in relation to defects recorded.

	AUG 18	AUG 20	AUG 23	AUG 24	AUG 35	AUG 50	AUG 60	AUG 65	AUG 72	AUG 73	AUG 78	AUG 81	AUG 82	AUG 83	AUG 84
supernumerary vertebrae							X		X						
precondylar tubercles	X														
bipartite hypoglossal canal		X	X			X						X			
bridging of the atlas			X				X					X			X
transitional facets on T11								X					X		X
sacralization of L5				X			X								
sacralization of first coccygeal segment											X			X	
clefting			X	X						X					
centrum hypoplasia					X										

continued...

Descriptions of individual burials from the **St Augustine the Less cemetery, Bristol** in relation to defects recorded.

	AUG 96	AUG 103	AUG 117	AUG 124	AUG 130	AUG 135
supernumerary vertebrae						
precondylar tubercles						
bipartite hypoglossal canal						X
bridging of the atlas				X		
transitional facets on T11		X			X	
sacralization of L5						
sacralization of first coccygeal segment						
clefting	X		X			
centrum hypoplasia						