To the Graduate Council:

I am submitting herewith a thesis written by David C. Jones entitled "Prehistoric Subsistence Patterns on the North Carolina Coast: Nutritional Status as Measured by Cortical Bone Area." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Anthropology.

Richard Jantz, Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council:

Vice Provost and
Dean of The Graduate School

Prehistoric Subsistence Patterns on the North Carolina Coast: Nutritional Status as Measured by Cortical Bone Area

A Thesis
Presented for the
Master of Arts
Degree

The University of Tennessee, Knoxville

David C. Jones
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ABSTRACT

Measurements of percent cortical bone area in femoral sections recovered from two geographically distinct areas of North Carolina are presented. The femora were recovered from archaeological sites 1) on the North Carolina coast and 2) in the North Carolina Piedmont. Both groups represent the Late Woodland. The Piedmont group relied on hunting-gathering, supplemented with insipient agriculture. The coastal group relied primarily (almost exclusively) on estuarine resources as a subsistence base. The mean percent cortical area was significantly higher in the coastal group, suggesting a better dietary adaptation. Additionally, anteroposterior and mediolateral diameters of the femoral sections were taken in order to assess mechanical stress on the lower limbs. These measures indicate that the Piedmont group may have tended towards a higher division of labor associated with subsistence activities.

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CHAPTER I

INTRODUCTION

Subsistence patterns and technologies of prehistoric peoples have long been vital aspects of archaeological research, contributing greatly to the knowledge of cultural evolution in the past. However, most studies regarding subsistence strategies have concentrated on large-bodied mammals such as the white-tailed deer, while the importance of smaller-bodied animals (including shellfish) has remained unclear (Klippel and Morey, 1986).

Additionally, it is only in recent studies that the analyses of human remains have been applied to the elucidation of subsistence strategies, the effects on the human populations which utilized those strategies (Huss-Ashmore et al., 1982; Cohen and Armelagos, 1984; Gilbert and Mielke, 1985) and the bearings those strategies have on cultural evolution (Larsen, 1987). These studies have led to the assessment and use of several skeletal features as indicators of nutritional stress which can be observed both macroscopically and microscopically.

With regard to nutrition, skeletal tissue responds to both the quality and quantity of the diet in a number of ways (Huss-Ashmore et al., 1982). One area of inquiry into these responses involves the study of the growth, maintenance and loss of cortical bone. No one indicator can consistently pin-point a single dietary deficiency, as a single nutrient deficiency alone usually does not create a stress. For example, laboratory animals subjected to a specific nutritional stress are usually reluctant to eat. Hence, they tend to suffer from a lack of

protein and calories to an unknown degree (Huss-Ashmore et al., 1982). However, measures of cortical bone area do appear to yield accurate and consistent indications of relative nutritional status in archaeological populations (Buikstra & Cook, 1980; Martin et al., 1985; Garn, 1970; Bordier et al., 1973).

Still, the use of cortical bone area as a tool for extracting information regarding diet does have its pit-falls. While nutritional deficiencies appear to have the greatest adverse effect on cortical bone (Huss-Ashmore et al., 1982), numerous other factors can also contribute to abnormal loss. These factors include immobilization and/or mechanical stressors (Ruff, 1987a; Fresia and Ruff, 1978; Ericksen, 1976), hormonal imbalance (Raisz and Kream, 1983; Cook et al., 1988), various disease states (Ortner and Putschar, 1985; Bogdan and Weaver, 1989; Garruto et al., 1989; Reichs, 1989) as well as the normal aging process (see e.g. Ericksen, 1976; Carlson et al. 1976).

This thesis presents measures of the percentage of cortical bone area as a primary determinant of the nutritional value of the diet utilized by prehistoric Late Woodland inhabitants along the coast of North Carolina. These data are combined with analysis of general pathologies, as well as archaeological, ecological and ethnohistoric data, to assess the degree of subsistence adaptation to the coastal environment. Additionally, the coastal sample is compared with samples from two Late Woodland sites located in the North Carolina Piedmont. The coastal inhabitants appear to have been adapted to a subsistence strategy depending primarily upon estuarine resources. The inland Piedmont aboriginals appear to have been in a transitory pattern, relying on agricultural products, while maintaining a partial reliance on hunting and gathering. Since hunter-gatherers usually exhibit a higher

health status in terms of nutrition (see e.g. Cook, 1979), the coastal sample should show a higher percent cortical bone area than the sample from the Piedmont region.

Further, comparisons are made between the coastal and Piedmont sites with regard to femur "shape", in order to assess sexual dimorphism relating to activity (primarily subsistence) patterns. Although hunter-gatherers typically exhibit a greater degree of division of labor by sex than agricultural populations (see e.g. Ruff, 1989), it is suggested here that the hunting-gathering coastal population may have had a more evenly distributed pattern of behavior. This should be reflected as a lesser degree of sexual dimorphism, in the coastal sample, in terms of femoral structure and mechanical loadings.

CHAPTER II

COMPOSITION AND DEVELOPMENT OF BONE

Increasingly, human bone is becoming a useful tool in the interpretation of cultural evolution from an archaeological perspective. The assessment of skeletal features (both microscopically and macroscopically) as indicators of diseases and nutritional stresses, is becoming useful in addressing questions regarding demographic change and patterns (Huss-Ashmore et al., 1982; Cohen and Armelagos, 1984; Gilbert and Mielke, 1985). Additionally, analysis of femoral structure and biomechanical loadings is currently being used to address behavior patterns in archaeological samples (Ruff, 1987a; Fresia and Ruff, 1978).

However, many problems exist with regard to the use of archaeologically recovered bone. First, samples of dry bone collected from an archaeological context offer no possiblities for the analyses of soft tissue or body fluids. Secondly, information on such traits as body weight, vital signs and geneological histories of disease is not made available. Additionally, archaeological samples are often of inadequate size or preservation and may or may not represent a good cross-section of the population which inhabited a given site. Moreover, dry bone samples reflect the interactions of the individual with their diet, the digestive and endocrine systems, disease, trauma and mechanical stresses acting upon the skeletal system prior to death, as well as diagenetic influences after interment. These problems make it very difficult to address

questions regarding a particular result of a specific condition. Therefore, a knowledge of the chemical composition of bone as well as an understanding of the processes involved in the development and maintenance of bone are essential if skeletal analyses are to yield accurate and reliable information upon which to base statements regarding past lifeways.

COMPOSITION OF BONE

In humans and the other placental mammals, bone is comprised of four basic constituents: 1) collagenous protein, 2) an amorphous ground substance, 3) bone mineral and 4) osteocytes.

The first of these constituents, collagenous protein, accounts for approximately 95% of bone tissue and confers upon bone its shape (Hancox, 1972). Collagen contains a very high proportion of the amino acids--proline and lysine. It is unique in that a considerable amount of the proline is hydroxylated (i.e. an hydroxyl group is added to it), becoming hydroxyproline. Hydroxyproline is not among the 20 amino acids directly coded by mRNA, so the synthesis of collagen requires extensive enzymatic modification of amino acids (Wallace et al., 1981).

Collagen is a fibrous protein constructed of aggregations of tropocollagen macromolecules. The tropocollagen molecules consist of three polypeptide chains which intertwine to form a triple helix. Each chain consists of sequences of three amino acids repeated along its course. In the sequence, the third amino acid is always glycine, the second is always either lysine or proline. The first in the sequence can be any of a variety of amino acids other than the next two (Ham and Cormack, 1979).

Each of the chains is linked together by elimination of a water molecule between the carboxyl group of one amino acid and the amino group of its neighbor. The amino acid residues along this tropocollagen monomer may be positively charged (e.g. lysine, arginine), negatively charged (e.g. aspartic acid, glutamic acid) or electrically neutral (e.g. alanine, valine). The distribution of the charged residues along the tropocollagen monomer is asymmetrical and the two ends of the molecules differ. In effect, the molecule has a head and a tail. Under normal conditions, lateral aggregation of tropocollagen molecules, overlapping longitudinally (head-to-tail), forms the collagen fibrils which make up the bulk of bone (Hancox, 1972).

When viewed under the electron microscope, the collagen fibrils display a characteristic cross banding pattern. The bands are apparently the areas where the tropocollagen molecules overlap each other (Hancox, 1972).

The amorphous ground substance of bone appears to be a mucopolysaccharide (a protein-carbohydrate complex). The structure of the ground substance also appears to consist of a central protein rod to which several chains of chondroitin sulphates are attached. The protein core is disordered and appears to lack a secondary or tertiary structure (i.e. the proteins are not spirally linked as in the collagen proteins), hence the term "amorphous" ground substance (Hancox, 1972). The ground substance remains somewhat obscure with regard to function. Smith and Frame, [1969 (cited in Hancox, 1972)] contend that the ground substance acts to hold the collagen fibrils in place. Hancox (1972) suggests that it may play a role in the calcification process and be the agency through which water is held and released.

The bone mineral is what confers upon bone its characteristic hardness. While the exact chemical composition of the mineral is unknown, it is made from calcium, phosphate and hydroxyl ions. Hancox, (1972) suggests that magnesium and strontium can replace calcium and that bicarbonate and fluoride can replace the hydroxyl ions. However, $Ca_{10}(PO_4)_6(OH)_2$ (calcium hydroxyapatite) is generally agreed to be the basic structure of the mineral. The exact morphological structure of the mineral is also unknown at present. However, a discussion of the mineral structure is beyond the scope of this thesis. The important aspect here is that the major constituents of the mineral are calcium and phosphate.

The fourth major constituent of bone is the osteocyte or bone cell. The major function of the osteocyte appears to be that of supplying nutrients to the bone tissue. The components of the osteocyte as well as the osteoblast and osteclast and their possible functions will be discussed later.

DEVELOPMENT OF BONE

Osteogenesis, or bone formation, occurs in two different microenvironments; 1) in areas of ordinary mesenchyme tissue, and 2) in areas of disintegrating cartilage. Bone forming in areas of mesenchyme (where no pre-existing cartilage was present) is referred to as intermembranous ossification (Ham and Cormack, 1979) and includes the face, cranial vault and clavicles (Matthews, 1980). Bone forming in the disintegrating central portions of the cartilaginous bones-to-be is called endochondral ossification (Ham and Cormack, 1979) and includes the appendicular skeleton, vertebral column and the base of the skull (Matthews, 1980). Ham and Cormack (1979) emphasize

that these two terms refer only to the environment in which bone was formed. They have no bearing on the process of ossification. The kind of bone which results from the two processes is the same.

Intermembranous Ossification

A good example of the process of intermembranous ossification is found in the formation of the parietal bone. In the parietal area of the cranial vault of the developing embryo, a layer of loose mesenchyme occupies the area between the developing brain and scalp. The mesenchyme consists of widely separated, star shaped cells with cytoplasmic processes that connect with the processes of other mesenchymal cells (Fig. II-1 A). In one or two areas, where abundant blood capillaries have infiltrated the tissue, a slight change in the cells (termed the osteogenic cell stage) occurs which represents the initiation of the formation of the *center of ossification*. This begins with a few of the mesenchymal cells becoming more rounded. At the same time, their processes thicken. This change represents the differentiation of the mesenchymal cells into bone forming cells called *osteoblasts* and may occur as a result of an increase in oxygen concentration which accompanies the assimilation of blood capillaries (Fig. II-1 B) (Ham and Cormack, 1979). The osteoblasts generate and secrete the organic matrix of bone. The osteoblasts themselves as well as their cytoplasmic processes act as "molds" around which the organic matrix is secreted. The osteoblasts continue to secrete the organic matrix until they (and their processes) are completely surrounded. Once the cells are surrounded by matrix, they are referred to as *osteocytes*, and are enclosed within *lacuna* in the matrix. Their cytoplasmic processes are now housed in small canals called

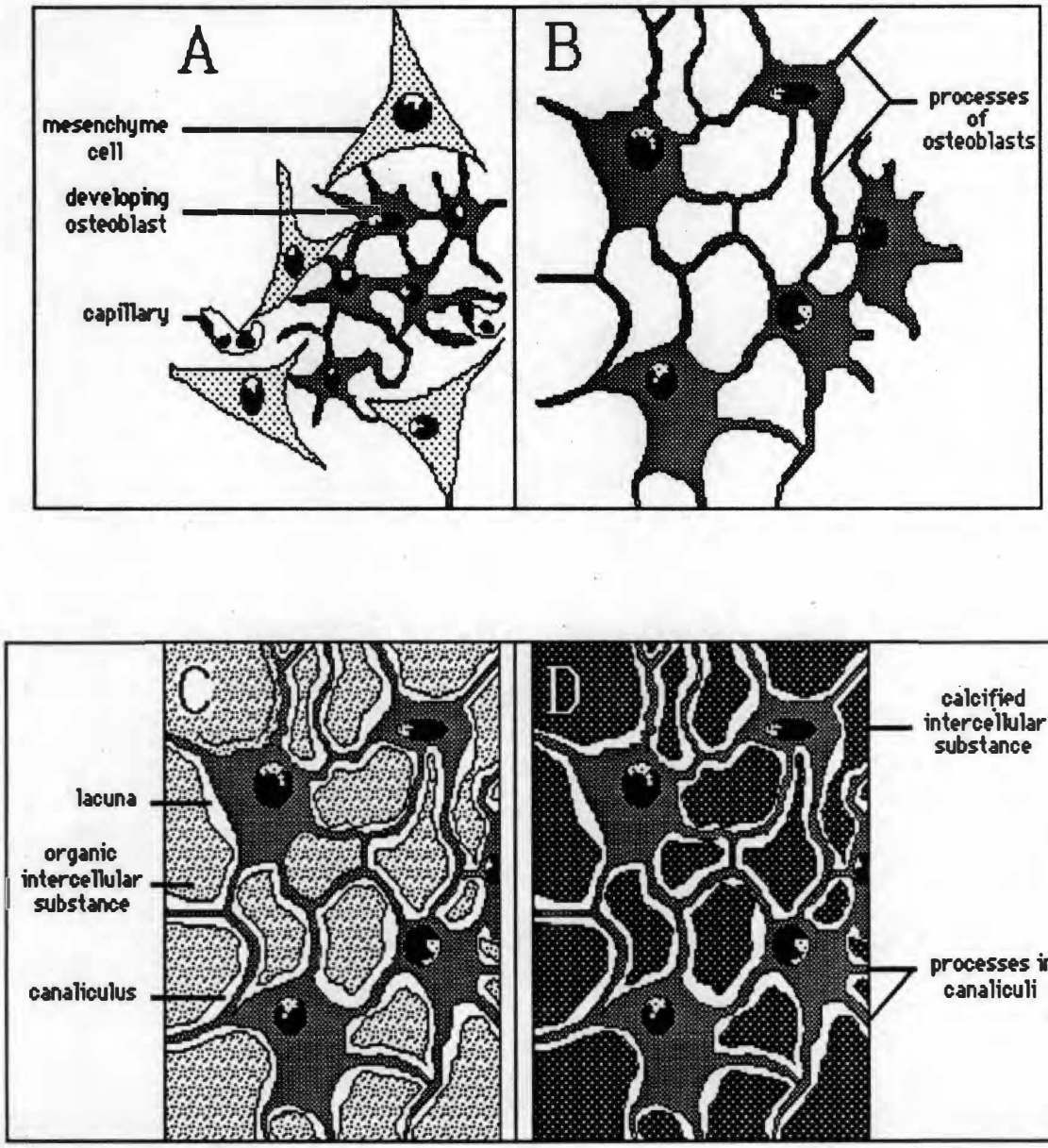


FIGURE II-1. Diagram of bone formation in an intermembranous environment. (A) Capillaries infiltrate an area of mesenchymal cells stimulating the cells to differentiate. (B) The cells are recognizable as osteoblasts. (C) They begin to secrete the intercellular substance around themselves and their canaliculi. (D) The cells are now completely surrounded by the matrix and are called osteocytes. (adapted from Ham and Cormack, 1979: 381).

canaliculi (Fig. II-1 C and D). The canaliculi, which are connected to nearby capillaries, become filled with tissue fluid. The fluid is passed on to the lacunae, thus keeping the osteocytes alive (Ham and Cormack, 1979).

The first small mass of bone to appear is usually in the form of an irregular bar called a bone *trabecula* . The growth of this first mass of bone is not due to its becoming evenly enlarged, but by the addition of other trabeculae extending out from it in a radial direction via appositional growth. These "trabecular extensions" are formed in the following manner: mesenchymal cells adjacent to the newly formed trabecula reach the osteogenic cell stage and begin to divide, thereby increasing their numbers (Fig. II-2). This allows some of the cells to differentiate into osteoblasts without exhausting the supply of osteogenic cells (Ham and Cormack, 1979). As the cells in this *osteogenic layer* (Urist, 1980) become osteoblasts, their processes remain in contact with both the osteocytes in the bone trabecula and the osteogenic cells in the osteogenic layer. These newly forming "trabecular extensions" connect with one another to form a network of bone referred to as *cancellous* bone (Ham and Cormack, 1979).

Cancellous bone is typically characterized as possessing more space occupied by loose connective tissue and blood vessels than by bone substance. Compact or cortical bone, on the other hand, possesses more bone than space. The spaces between the trabeculae of cancellous bone decrease in size as new bone matrix is deposited. The new bone trabeculae are deposited in layers. This layering leads to a circular structure which houses a central canal containing at least one blood vessel. These circular structures are called Haversian systems or osteons (Fig. II-3). Osteons fill the spaces

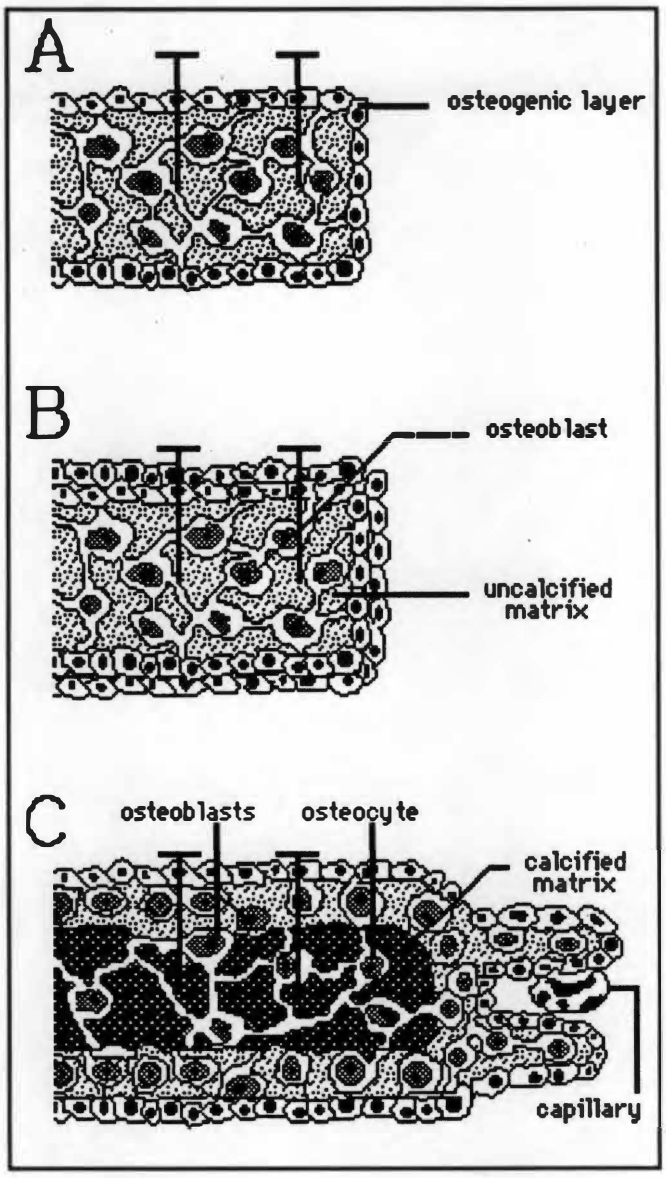


FIGURE II-2. Diagram of appositional growth in a bone trabecula. (A) shows a bone trabecula surrounded by mesenchymal cells making up the osteogenic layer. (B) the cells in the osteogenic layer begin to multiply, thereby enabling some of the cells to differentiate into osteoblasts without exhausting the supply of cells. (C) the osteogenic cells of the deeper layer differentiate into osteoblasts and secrete the bone matrix. The capillary to the right of the trabecula is incorporated into the bone so as to provide nutrition to the osteoblasts and osteocytes. The "T" markers remain in the same position in (A), (B) and (C) indicating that the bone grows appositionally as opposed to interstitially. (adapted from Ham and Cormack, 1979: 383).

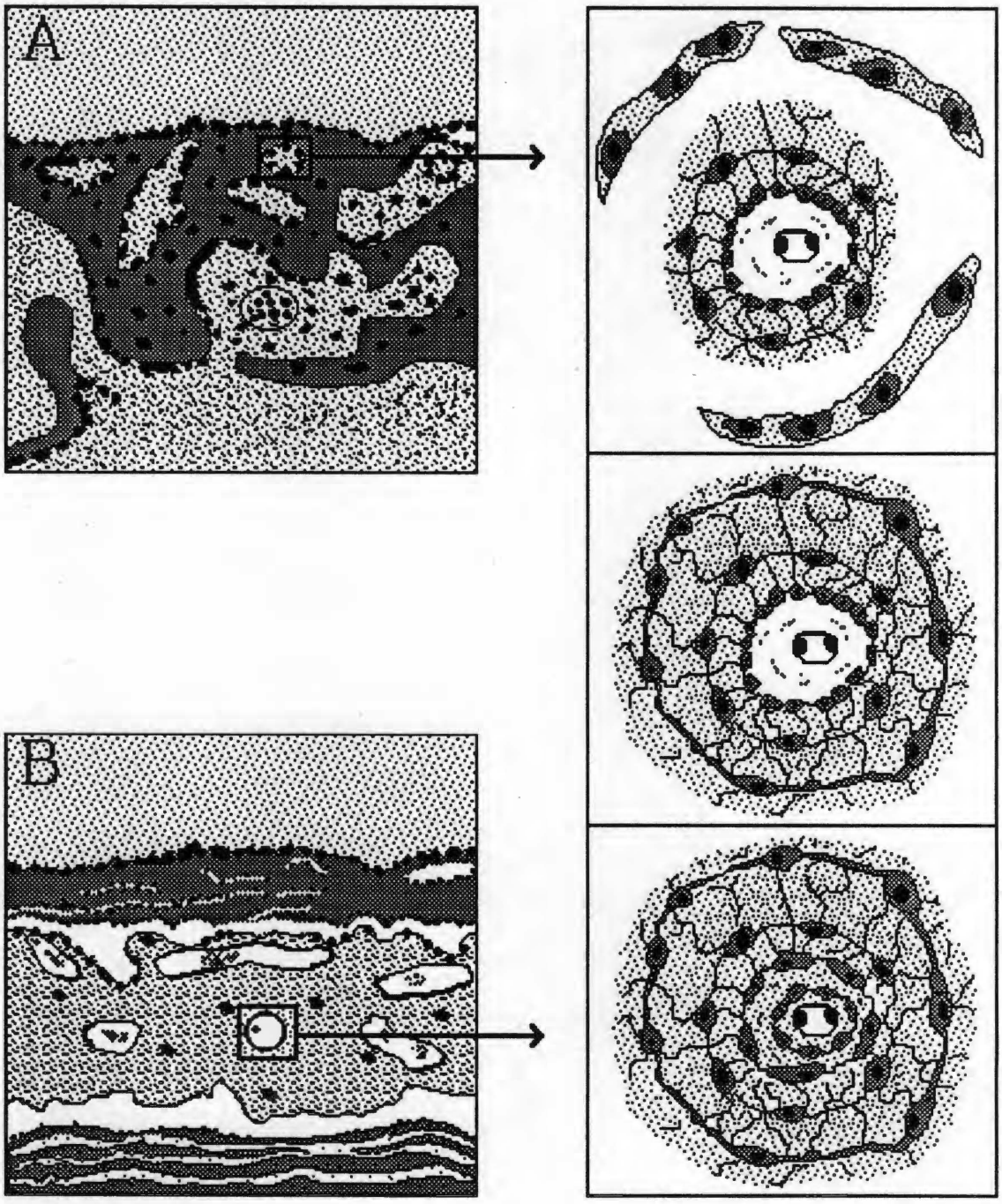


FIGURE II-3. Diagram of cancellous bone being converted to compact (Haversian) bone. (A) cancellous bone showing large spaces between trabeculae. (B) compact bone depicting spaces now occupied by bone (adapted from Ham and Cormack, 1979: 385).

between trabeculae in cancellous bone, thus converting it to compact bone (Ham and Cormack, 1979).

Endochondral Ossification

As mentioned previously, bone is formed in two types of microenvironments. Endochondral (within cartilage) ossification gives rise to most of the skeleton. An appropriate example of endochondral ossification is the development of the long bones.

As the embryo develops, small appendages called limb buds extend from its trunk. The buds consist of mesodermal outgrowths covered with ectoderm. The first sign of bone formation begins during the fourth week of uterine development (Burdi et al., 1976) with mesenchymal cells of the limb buds becoming tightly packed together (Fig. II-4). Next, the cells in the central core of the packed mesenchyme (the diaphysis-to-be) begin to differentiate into chondrocytes and secrete the cartilage matrix. This results in a separation of the cells. The mesenchyme immediately adjacent to the developing cartilage becomes condensed to form a surrounding membrane called the *perichondrium*. The perichondrium eventually develops into two layers. The cells in the outer layer differentiate into fibroblasts and form collagen. Those of the inner layer remain undifferentiated and constitute the chondrogenic layer (Ham and Cormack, 1979).

The cartilage model increases in width initially via interstitial growth. The majority of the increase in width, however, is due to appositional growth. New layers of cartilage are added to the sides of the model by the proliferation

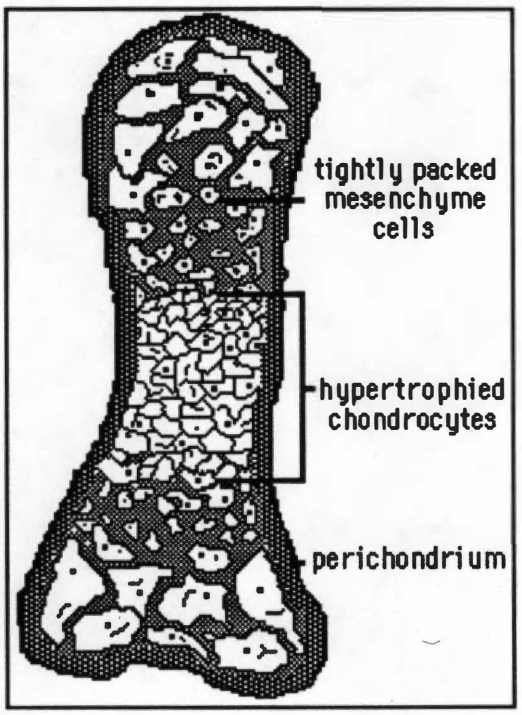


FIGURE II-4. Diagram of limb bud development. Hypertrophy and necrosis of the chondrocytes begins at about the eighth week of uterine development (adapted from Burdi et al., 1976; 9).

and differentiation (into chondrocytes) of the cells in the chondrogenic layer of the perichondrium (Ham and Cormack, 1979).

The increase in length of the cartilage model is accomplished solely by interstitial growth. This involves both the division and enlargement of the chondrocytes as well as the formation of additional intercellular substance.

Most of the cell divisions responsible for the interstitial growth in length of the model occur at the ends. As the bone grows in length, the cells initially at the end of the model become incorporated in the center, where they have time to mature. Simultaneously, the intercellular substance in the center of the model becomes thinned out. This allows for the deposition of calcium salts. Once the mid-section of the model becomes sufficiently calcified, diffusion of nutrients through the model ceases (Ham and Cormack, 1979). At approximately the eighth week of gestation (Burdi et al. 1976), hypertrophy and necrosis of those chondrocytes begins. During the period in which the mid-section changes are taking place, the development of the vascular system of the embryo leads to an invasion of the perichondrium of the model by capillaries (Fig. II-5). When a sufficient amount of capillaries has become manifested in the perichondrium, the cells of the chondrogenic (inner) layer begin to differentiate into osteoblasts and osteocytes rather than chondrocytes. This change in the differentiation pattern is probably due to a greater concentration of oxygen brought into the perichondrium by the capillaries (Ham and Cormack, 1979). The result is that a thin layer of bone is soon deposited around the inner portion of the shaft of the model. Since the perichondrium now covers a thin layer of bone, it is referred to as the *periosteum*.

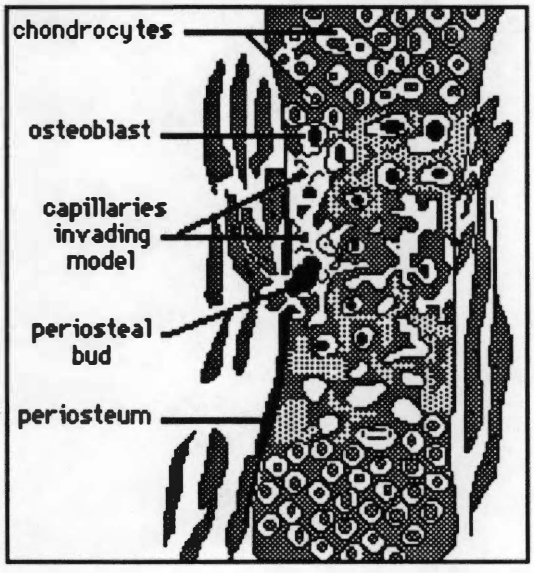


FIGURE II-5. Diagram of the invasion of the perichondrium of the model by capillaries. The cells of the chondrogenic (inner) layer of the perichondrium have begun to differentiate into osteoblasts and are depositing bone around the inner portion of shaft of the model, thus forming the periosteum and the periosteal bud. The periosteal bud later becomes the entry and exit of the nutrient artery and vein, which sustain the bone and support the maintenance of the bone tissue. (adapted from Ham and Cormack, 1979: 425).

Further invasion of the central core of the model by capillaries, and hence osteoblasts, leads to the formation of the *periosteal buds* on the periphery of the degenerating calcified cartilage.

When the capillaries and osteoblasts of the periosteal bud reach the interior of the model, they constitute a *diaphyseal center of ossification* and will spread from that point via appositional growth to replace most of the cartilage (Ham and Cormack, 1979). The site of the periosteal bud later becomes the site of the entry and exit of the nutrient artery and vein of the bone (Urist, 1980). Just as in intermembranous ossification, the first bone apposed on the degenerating cartilage is in the form of a trabecula and is thus, cancellous bone. The cancellous bone is converted to compact bone as previously described.

The development of the long bones, in addition to the diaphyseal center of ossification, depends on *epiphyseal centers of ossification* as well. In the epiphysis, the bone grows in a radial direction from the center of ossification. However, osteogenesis stops short of replacing all the cartilage. A layer of *articular cartilage* remains at the extreme end, while another layer of cartilage (the *epiphyseal disk*) remains between the epiphysis and diaphysis (Fig. II-6). The epiphyseal disk allows for the continued growth in length of the long bone. Chondrocytes continue to grow interstitially and secrete matrix on the epiphyseal side of the disk. Meanwhile, capillaries and subsequently osteoblasts invade the degenerating calcified cartilage from the diaphyseal side of the disk. In this area, the osteoblasts deposit bone matrix. Hence, the diaphysis increases in length. It should be noted that the continued proliferation of cartilage on the epiphyseal side of the disk does not "shorten" the epiphysis. It simply "pushes" the epiphysis away from the diaphysis (Ham and Cormack,

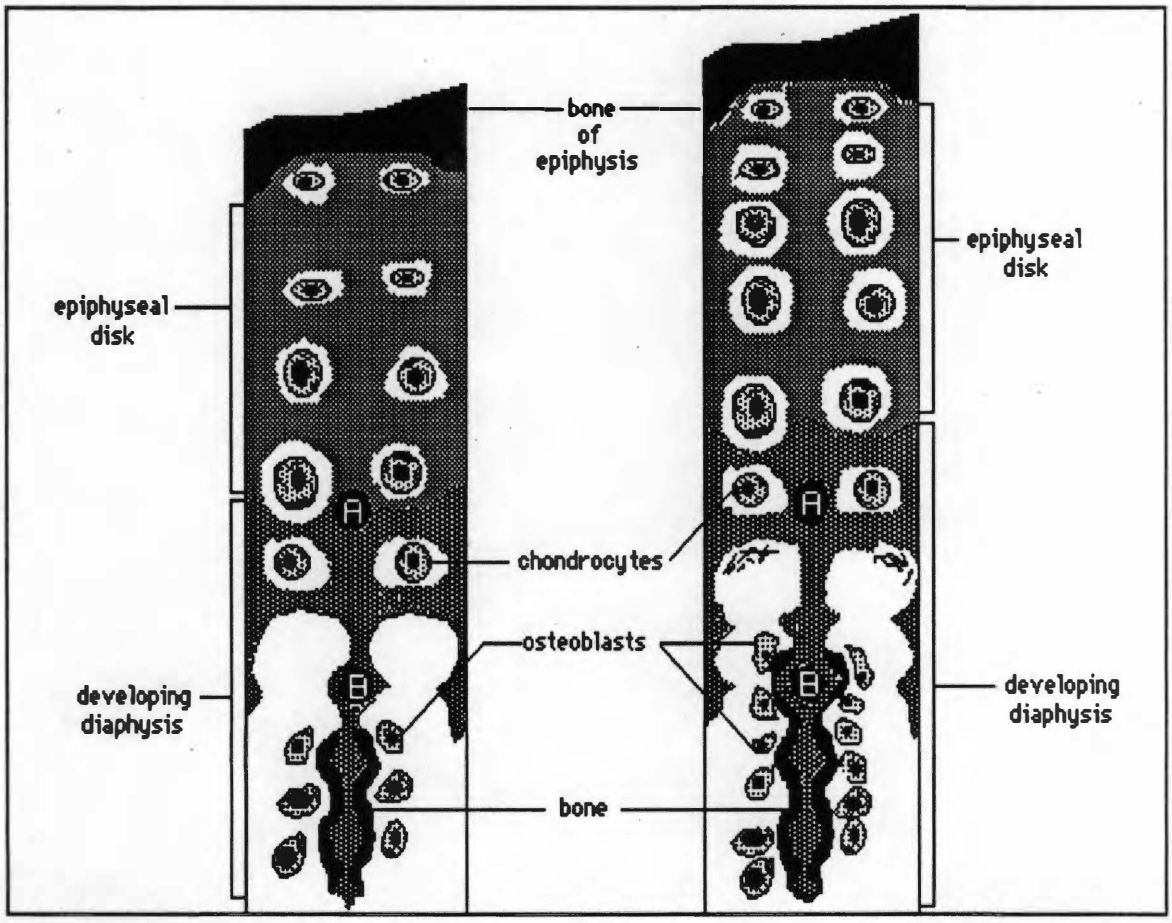


FIGURE II-6. Diagram of epiphyseal growth in a long bone. Points A and B do not change position indicating that the interstitial growth simply pushes the epiphysis away from the diaphysis (adapted from Ham and Cormack, 1979: 430).

1979). Essentially then, a persistent "race" occurs between two opposing processes: 1) interstitial growth which tends to thicken the epiphyseal disk and 2) replacement of cartilage with bone on the diaphyseal side of the disk which tends to make the disk thinner. This "race" is eventually won by the latter process, but only after full length (maturity) is obtained (Ham and Cormack, 1979).

When viewed in longitudinal section, the chondrocytes in the epiphyseal disk are aligned in columns (Fig. II-7). The cartilage matrix between the columns actually serves as the "walls of tunnels" in which the chondrocytes reside. As the chondrocytes towards the diaphyseal side of the epiphyseal disk die, the bone replacing them is actually deposited inside the walls of the tunnels. On the periphery of the bone, several layers of bone are apposed so that a given tunnel eventually becomes a narrow canal containing at least one blood vessel, several osteoblasts and occasionally a lymphatic. This arrangement of a canal with concentric layers of bone surrounding it constitutes, as mentioned previously, an Haversian system or osteon (Ham and Cormack, 1979).

The incorporation of Haversian systems into new bone formed in areas other than the periphery of the epiphyseal disk is accomplished in the following manner: the bone immediately beneath the periosteum is not in the form of a smooth, flat surface but actually consists of small ridges (Fig. II-8). The osteoblasts in the periosteum covering the ridges deposits bone matrix in order to extend the ridges towards one another until they meet. This converts the "grooves" between ridges into tunnels. Since the grooves were initially lined with periosteum containing osteoblasts and blood vessels, the tunnels

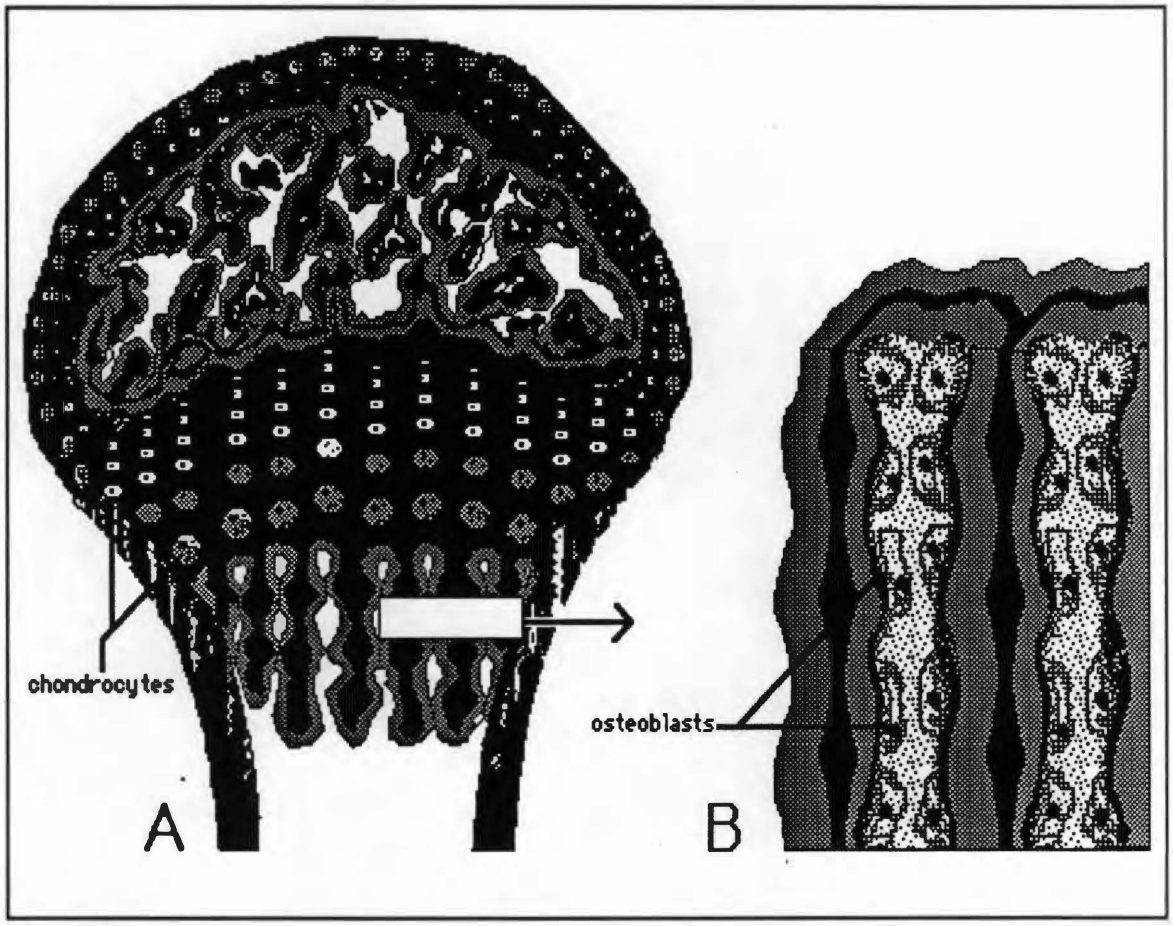


Figure II-7. Diagram of growth on the periphery of long bones. A) shows longitudinal section of femur, while B) shows osteoblasts depositing bone matrix inside walls of tunnels (adapted from Ham and Cormack 1979: 436).

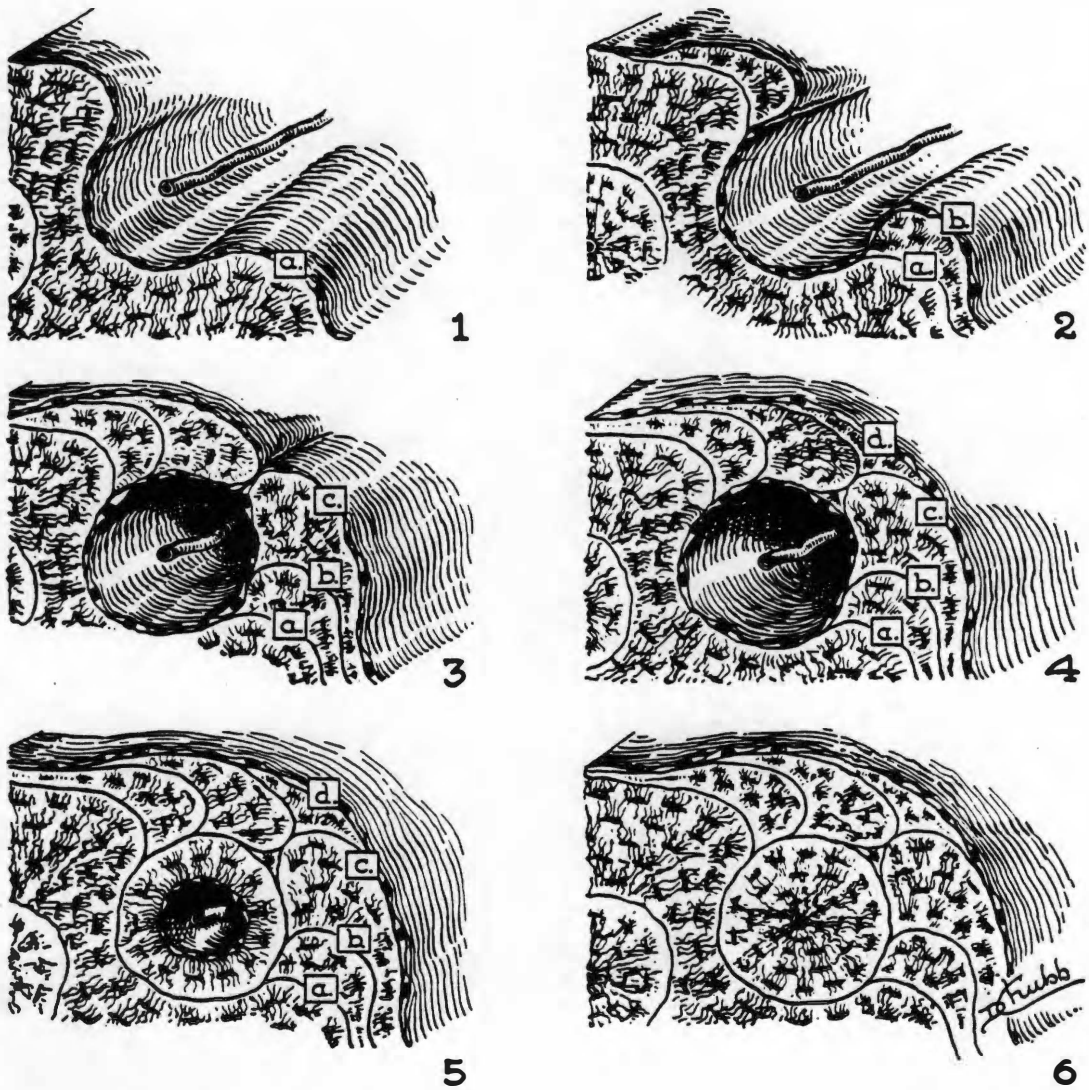


Figure II-8. Diagrams of the incorporation of Haversian systems into new bone shaft. Letters a-d indicate the successive layers of deposited bone (adapted from Ham and Cormack 1979:439).

now contain osteoblasts and at least one blood vessel. The continued excretion of bone matrix by the osteoblasts within the tunnel converts it into an Haversian system.

The resorption of old bone and the deposition of new bone does not cease when full growth is obtained (Garn, 1970). The skeletal system, like any other system in the body, must be maintained, i.e. dead tissue must be removed and replaced with newly formed tissue. Following a brief description of the bone cells (osteoblasts, osteocytes and osteoclasts), their functions and probable origins, a discussion of the process of bone remodeling will be presented.

Osteoblasts

Osteoblasts originate from ordinary mesenchymal cells which differentiate into "bone forming" cells in the presence of blood capillaries, i.e. increased concentrations of oxygen (Ham and Cormack, 1979). The primary function of osteoblasts is to synthesize and secrete the organic matrix of bone (Hancox, 1972) and to do this around themselves and their cytoplasmic processes in order to cause the formation of canaliculi (Ham and Cormack, 1979).

The osteoblast has the same fine structure as any secretory cell. When viewed under the electron microscope (Urist, 1980), the osteoblast reveals a cytoplasm occupied primarily by rough endoplasmic reticulum with a large Golgi complex and scattered mitochondria. In other secretory cells, e.g. epithelial gland cells, the endoplasmic reticulum is located at the base of the cell, with the Golgi above the nucleus. The secretory vesicles budding from the Golgi travel to the apical region of the cell where their contents are secreted (Ham and Cormack, 1979). In the osteoblast however, the rough endoplasmic

reticulum is widely distributed. The Golgi complex lies near the side of the nucleus facing the bulk of the cytoplasm. Secretory vesicles can be seen throughout the cytoplasm. Ham and Cormack (1979) suggest that this organellar arrangement may allow the osteoblast to secrete the bone matrix from any point along the cell membrane and thus surround itself with matrix.

Actin-containing microfilaments (King and Holtrop, 1975) occupy the peripheral areas of the cytoplasm (Cameron, 1972) and the cytoplasmic processes. Ham and Cormack (1979) suggest that the microfilaments may act to move tissue fluid through the canaliculi, thus providing nutrients to the osteoblast.

Osteocytes

Osteocytes are simply osteoblasts which have become completely surrounded by bone matrix (Urist, 1980). The processes of osteocytes remain in contact with those of adjacent osteocytes by means of gap junctions (Ham and Cormack, 1979). Like osteoblasts, young osteocytes contain abundant rough endoplasmic reticulum and a large Golgi complex. The mitochondria in osteocytes are larger, but less numerous than those found in osteoblasts. As the osteocyte ages, the rough endoplasmic reticulum, the Golgi complex and the number of mitochondria are all greatly reduced. At this point, the osteocytes are relegated primarily to a maintenance role (Urist, 1980). A further function suggested by Parfitt (1984) is that osteocytes may secrete suppressor agents, e.g. prostacyclin to stop the resorption process carried out by osteoclasts.

Osteoclasts

Unlike osteoblasts and osteocytes, osteoclasts originate from hematopoietic stem cells (Ham and Cormack, 1979; Parfitt, 1984). The osteoclast is the cell responsible for the resorption of bone mineral and possibly collagen (Urist, 1980). They are very large, multinucleated cells seen on bone surfaces where resorption is occurring. Their resorptive activity is evidenced by the fact that they are usually housed in "pits" termed *Howships lacunae* or cutting cones (Parfitt, 1984).

The osteoclast consists of four major components of fine structures:

1) The ruffled border - This is a region of the cytoplasm which exhibits folds and processes whose tips reach and often project into the bone surface.

2) The clear zone - This area abuts on the bone and, like a girdle, surrounds the region of the ruffled border. This area of cytoplasm contains no organelles, but many actin containing fibers. One theory of the function of the clear zone is that it anchors the ruffled border of the osteoclast firmly to the bone surface (Matthews, 1980; Bonucci, 1981). A second possibility is that the filaments act to agitate the folds of the ruffled border, thus aiding the resorption process (Ham and Cormack, 1979).

3) The vesicular region - The vesicular region is actually the inner portion of the ruffled border. It is characterized by the presence of numerous membrane bound vesicles.

4) The basal region.- This portion of the osteoclast contains the many nuclei, some rough endoplasmic reticulum, many Golgi saccules and numerous mitochondria.

The function of the osteoclast appears to be restricted to bone resorption. This function will be discussed as part of the larger process of bone remodeling.

BONE REMODELING

The term bone remodeling as used here refers to the bone replacement processes in the adult human skeleton. These processes serve to prevent the accumulation of fatigue damage and maintain an adequate supply of young bone of relatively low mineral density to subserve mineral homeostasis (Parfitt, 1984; p S36).

Bone remodeling occurs in five successive stages of 1) quiescence, 2) activation, 3) resorption, 4) reversal, 5) formation, and back to quiescence. The coordination of cell activity in this sequence, described as the skeletal intermediary organization (Frost, 1980), depends on local signals to or between cells (Parfitt, 1984).

Quiescence

In the adult human approximately 95% of intracortical bone surface is in the quiescent, or inactive stage (Parfitt, 1983). The structure of the surface of quiescent bone is very complex, with a very thin (0.1-1.0 micron) layer of lining cells between the cortical bone matrix and the marrow cavity. Cytoplasmic processes from these cells extend into the canaliculi and maintain contact with the osteocytes in the matrix. The lining cells probably originate from osteoblasts but have apparently lost the ability to synthesize bone matrix.

Activation

Initiation of the activation stage requires 1) the recruitment of osteoclast cells, 2) a means by which they can gain access to the bone surface and 3) a mechanism for their attraction and attachment to the bone surface (Parfitt, 1984).

Teitelbaum and Kahn (1980) and Malone et al. (1982) suggest that the lining cells release factors which provide chemotactic signals calling for mononuclear preosteoclast precursor cells (POC's). At some point after the POC's accumulate in a given local area, osteoclasts begin to form. Chambers (1980) suggests that the simple contact of the POC's with the lining cells stimulates these cells to fuse, forming the multinucleated osteoclasts. Heersche (1978) suggests that some of the POC's remain unfused and act to resorb the collagen fibers, leaving the resorption of the mineral matrix to the osteoclasts. Nonetheless, once the POC's and osteoclasts accumulate in a given vicinity they must have access to the bone mineral which is covered by the lining cells. Therefore, the POC's and osteoclasts must penetrate the lining cells. Whether this involves perivascular migration, morphologic changes in the lining cells (Rodan and Martin, 1981) or lysis of the lining cells (Parfitt, 1984) is unknown. However, once the lining cell layer has been penetrated, the clear zone of the osteoclast attaches to the bone surface (Matthews, 1980; Bonucci, 1981) and resorption begins.

Resorption

Once the clear zone has attached to the bone surface, the osteoclast begins to erode the cavities known as Howships lacunae or cutting cones. The

osteoclast appears to be motile and able to resorb bone over an area larger than the area with which it is in contact at any given time (Parfitt, 1983). Additionally, Vaugan (1981) suggests that resorption of the bone may continue for several hours after the osteoclast has vacated an area. Apparently, the continuation of resorption is carried out by the monocytic POC's which have failed to fuse or by other resorbing monocytic cells (Parfitt, 1984).

The resorption front, i.e. the activity of the entire osteoclast team, moves approximately 5-10 nanometers per day perpendicular to the eroded surface and about 20-40 nanometers per day parallel to the eroded surface. When the Howships lacunae reach a depth of about 100 nanometers in cortical bone, resorption usually ceases. The process governing the size, shape and depth of the lacunae is unknown (Parfitt, 1983). Chambers (1980) suggests that the layer of lining cells may be involved in the termination of resorption. Parfitt (1984) notes that the lining cells may produce prostacyclin, a substance which inhibits osteoclastic activity. However, the osteoclasts get progressively further from the lining cells as resorption continues and osteocytes may be utilized at this point for communication between the two. Parfitt (1984) suggests that the lining cells may stimulate the osteocytes which in turn may stimulate the osteoclasts to cease resorption.

Reversal

The reversal stage is the time during which events occur that serve to couple the resorption and formation stages. Reversal is first recognized by the presence of Howships lacunae which are lacking osteoclasts. At this time, mononuclear cells are seen on the edges of the Howships lacunae. These cells

smooth over the ragged edge left by the osteoclasts and deposit a thin layer of highly mineralized matrix known as cement substance. The nature, origin and relationship of these cells to the osteoclasts and POC's is unknown (Parfitt, 1984).

Successful coupling of the resorption and formation stages requires the appearance of osteoblasts at the bases of the Howships lacunae, which must involve 1) a mechanism by which to attract the osteoblasts and osteoblast precursor cells to the lacunae, and 2) a stimulus to initiate cell division. A substance released from the matrix during resorption will naturally be in highest concentration where new osteoblasts are most needed. This substance could stimulate osteoblasts and osteoblast precursor cells to migrate to the areas where active resorption is taking place. A substance known as human skeletal growth factor, which stimulates osteoblast proliferation and induces bone formation, usually appears near the vacated Howships lacunae (Parfitt, 1982).

Once the osteoblasts have been recruited to the area of resorption, they must become aligned on the surface of the edge of the Howships lacunae. This may occur as a result of a chemotactic signal derived from the cement substance (Parfitt, 1984). Following alignment of the osteoblasts, the process of bone formation can begin.

Formation

The primary function of the osteoblast is the manufacture and deposition of the organic matrix of bone. Once the organic matrix has been apposed and mineralization has occurred, the formation process is complete. In order for mineralization to occur, however, the organic matrix must mature and have an

adequate supply of calcium and phosphate (Parfitt, 1983). While the maturation process is poorly understood (Parfitt, 1984), it does result in a time delay between the apposition of the organic matrix and the process of mineralization.

The osteoblasts secreting the matrix are separated from recently mineralized bone by a layer of osteoid, or unmineralized bone. As a given Howships lacuna becomes nearly filled with new matrix, the osteoblasts begin to undergo a morphological change. Their nuclei become flatter and broader and their cytoplasm becomes less abundant. Additionally, the rate of apposition of matrix decreases. The mineralization process continues until the osteoid disappears and the osteoblasts remaining on the surface undergo the morphological change. These remaining osteoblasts cease to function as matrix manufacturers and serve as the lining cells and the bone returns to the quiescence stage (Parfitt, 1984).

Several factors can disturb the normal processes discussed above. These factors include disturbances in mechanical loads (Ruff, 1987a; Martin et al., 1985; Ham and Cormack, 1979; Fresia and Ruff, 1978; Ericksen, 1976), hormonal imbalance (Cook et al., 1988 Raisz and Kream, 1983;), trauma (Ortner and Putschar, 1985), various disease states (Bogdan and Weaver, 1989; Garruto et al.,1989; Reichs, 1989; Ortner and Putschar, 1985), as well as the normal aging process (see e.g. Ericksen, 1976; Carlson et al., 1976). While all the variables affecting bone processes are complex and often act synergistically, perhaps the most significant factor involved concerns the quality and quantity of the diet (Huss-Ashmore et al., 1982). As mentioned above, ingestion of calcium and phosphates is essential to the normal development of bone. Additionally, ade-

quate amounts of protein and calories are paramount to the normal growth, development and maintenance of the skeletal system. The following chapter reviews the anthropological literature which has dealt with the interactions of nutrition and skeletal maintenance.

CHAPTER III

CORTICAL BONE AND NUTRITIONAL STATUS: A LITERATURE REVIEW

That loss of cortical bone and mineral content is associated with protein-calorie deficiency has become accepted as a basic tenet in the medical field (Ham and Cormack, 1979). This has become even more clear since the invention of x-rays. Accordingly, the measurement of the amount of cortical bone present in a given bone sample has become a commonly accepted indicator of nutritional stresses in archaeological populations.

Aside from normal age-related bone loss, anthropological interest in the area of cortical bone thickness generally involves four inter-related avenues of research: 1) mechanical stresses (Ruff, 1987a; Fresia and Ruff, 1978; Ericksen, 1976); 2) hormonal imbalances (Raisz and Kream, 1983; Cook et al., 1988); 3) various disease states (Ortner and Putschar, 1985; Bogdan and Weaver, 1989; Garruto et al., 1989; Reichs, 1989) and 4) nutrition (Buikstra & Cook, 1980; Martin et al., 1985; Garn, 1970; Bordier et al., 1973; Ericksen, 1976; Perzigian, 1973).

Garn et al. (1964) conducted what may have been the first truly anthropological study utilizing the measurement of cortical bone. In this study, observations were made of routine radiographs taken of 95 infants and children hospitalized in Guatemala as a result of protein-calorie malnutrition. The ra-

diographs indicated that cortical bone in 75% of the patients was much thinner than the village trend for normal individuals of both sexes.

Garn et al. (1969) added to their data by studying 91 Guatemalan boys hospitalized with an admission diagnosis of kwashiorkor. Their observations revealed no reduction in width of metacarpals, but did show a reduction in cortical area and percent cortical area. The authors attributed the reductions in cortical area to normal apposition at the subperiosteal border with excessive endosteal resorption.

Dewey and co-workers (1969) took measurements of femoral cortical thickness of archaeological specimens from three distinct cultures from Sudanese Nubia. The sample was drawn from cemeteries associated with three village sites: 1) the Meroitic (0 B.C.- A.D 350), 2) X-Group (A.D. 350-550) and 3) Christian (A.D. 550- 1300). The three groups are divided culturally based upon significant political and religious changes incurred over time; however, biologically and technologically, they represent a homogeneous lineage. The inhabitants were intensive agriculturalists, relying primarily on grains such as millet, sorghum and barley (Martin and Armelagos 1985). The results of the study revealed no significant sex specific differences in cortical thickness among either of the three cultural groups. However, the research did indicate that bone loss occurred earlier and more dramatically in females than in males within each cultural group. This observation was attributed to a combination of inadequate calcium intake and extended lactation.

Van Gerven et al. (1969) compared roentgenographic and direct measurements of femoral cortical thickness from a prehistoric Mississippian population. The authors observed a greater amount of bone loss in the females

than in the males. However, they made no attempt to suggest causes for the different rates. The main thrust of the study was to compare roentgenographic measurements with direct measurements. The study revealed errors resulting from inaccurate representation of the bone in radiographs. Van Gerven et al. (1969) subsequently suggested the use of direct measurements in future research.

Adams and Berridge (1969) measured metacarpal cortical thickness from x-rays of 19 children with kwashiorkor from the Baganda tribe of Uganda. These measurements were compared to 17 healthy children also of the Baganda tribe. The healthy children were considered to exhibit normal growth patterns by local standards. The children with kwashiorkor exhibited retarded growth rates in terms of total body length as well as significant deficiencies in both cortical and trabecular bone in comparison to the healthy children. The diseased children were subsisting on a diet low in protein, calcium and phosphorous. Adams and Berridge (1969) suggested that the deficiency in protein may have been the major cause of bone loss because protein is essential for the growth of all body tissues and that the protein deficiency may have inhibited the resorption of calcium.

During the decades of the 1970's and 1980's numerous studies involving cortical bone have been undertaken. Armelagos et al. (1972) studied the rate of bone development and age-related changes in the internal structure of the femur of specimens from Sudanese Nubia. It was determined that growth velocity of long bones was similar to that found in American boys. Growth symmetry of long bones exhibited more stability than that which occurs in American boys. However, substantiating the findings of Dewey et al. (1969), it

was observed that the females suffered a significant loss of cortical bone with age, while males did not.

Perzigian (1973) utilized photon absorptiometry to compare bone loss in two archaeological populations--Indian Knoll (Archaic hunter-gatherers) and Pete Klunk (Hopewell) sites. The Indian Knoll inhabitants were exclusively hunter-gatherers, while the Hopewell group supplemented hunting-gathering with agriculture. Perzigian suggested that the Hopewell culture provided a more nutritionally sufficient diet than that of the Indian Knoll. While the photon absorptiometric data indicated that the Hopewell inhabitants lost cortical bone at a greater rate than that of the Indian Knoll inhabitants, Perzigian would not go so far as to say that diet was partially responsible. His conclusion was that diet is not a significant contributing factor in skeletal maintenance during aging.

Himes et al. (1975) observed significantly less metacarpal cortical bone in 710 moderately malnourished Guatemalan children when compared to well-nourished children of the same age and sex, as well as those of the same body weight and stature. In previous studies (e.g. Adams and Berridge, 1969; Garn et al. 1969) comparisons were made between severely malnourished and moderately malnourished children, rather than between well-nourished and severely malnourished children. Thus, Himes et al. (1975) suggested that chronic malnutrition affects cortical bone more than acute, usually rapidly precipitated bouts with kwashiorkor.

Ericksen (1976) measured medial-lateral cortical thickness of the femur and humerus and anterior cortical thickness of the femur alone. Her sample consisted of archaeological samples from Eskimo, Pueblo and Arikara sites.

The results of this study indicated that the medial-lateral femoral thickness was much greater in the Eskimo than in the Pueblo, with the Arikara generally falling between them, except in old age. Medial-lateral thickness also indicated that females lost more bone in old age than did males for all three populations. Anterior cortical thickness of the femur was similar in all three groups, but again indicated a significant loss of bone in females. The medial-lateral thickness of the cortex in the humerus reflected that of the anterior femoral cortex. Although subsistence bases differ dramatically between these groups, Ericksen (1976) dismisses nutritional deficiencies as a contributing factor in bone maintenance. The author states that bone function serves as a primary factor in bone maintenance. Ericksen (1976) suggests that the weight-bearing anterior portion of the femur mid-shaft accounts for the similarities in this variable, while the non-weight bearing medial-lateral portion is subject to a greater degree of bone loss, leading to the differences in medial-lateral cortex thickness between the three groups.

Richman et al. (1979) compared type II (within the walls of Haversian canals) cortical bone remodeling processes of Eskimo, Arikara and Pueblo archaeological populations. The Eskimo, with a high protein diet exhibited the most frequent type II remodeling. The Pueblo, with a very low protein diet (maize accounted for approximately 80-85% of the diet) exhibited the least amount. The Arikara, who supplemented maize with quantities of meat fell between the Eskimo and Pueblo sample. Richman et al. (1979), unlike Ericksen (1976) attributed the differences to nutrition. It was suggested by Richman et al. (1979) that a high protein diet which causes metabolic acidosis (possibly ketosis), which is associated with bone loss, could account for the high inci-

dence of type II structures in the Eskimo sample by causing more frequent mobilization of available mineral from bone to serve as buffers in extracellular fluids. Additionally, the Eskimo diet may be low in calcium, which would add to problems with bone maintenance. Thompson and Gunness-Hey (1981) also found Eskimo samples lacking in cortical thickness when compared to well-nourished United States Caucasians. While Thompson and Gunness-Hey (1981) warned that physical activity and body size may be a factor, diet was suggested as the major cause.

Martin and Armelagos (1979) analyzed microradiographs as well as measures of cortical thickness and cortical area of femora from the X-Group population of Sudanese Nubia. Their findings substantiated other studies, revealing that females tend to exhibit a greater amount of bone loss (osteoporosis) at an earlier age of onset than do males. They suggested, as others have, that nutritional stress combined (and associated) with pregnancy, lactation and workloads may have resulted in the marked bone loss in the females.

Cook (1979) reported on the interactions of demographic, skeletal and nutritional variables during the transition from hunting-gathering to maize agriculture-based subsistence strategies which occurred in the Lower Illinois Valley from the Middle Woodland to Late Woodland/Mississippian. Specifically, data were gathered and analyzed on population dynamics, Harris lines, cortical bone loss and nutritionally-related dental pathologies. All direct measures of health status indicators (cortical bone thickness and dental pathologies) indicated a decrease in health status immediately before and after the adoption of agriculture as a subsistence base. Cook (1979) suggested that this pattern was

best accounted for as indicating protein-calorie malnutrition during the transition.

Hummert (1983) measured subperiosteal area, cortical area, medullary area and percent cortical area at the tibia mid-shaft in a sample of sub-adults from a Medieval Christian (A.D. 550-1450) population in Sudanese Nubia. He reported that total area and cortical area, as well as length, appeared to be normal and well-maintained, indicating that subperiosteal apposition of new bone was normal. However, excessive endosteal resorption had resulted in low percent cortical area. This growth pattern probably reflects acute periods of nutritional stress, while chronic nutritional deficiencies play a larger role in depressing subperiosteal apposition [Himes, 1978 (cited in Hummert, 1983)].

Martin and Armelagos (1985) conducted a further study on the Sudanese Nubia archaeological populations. They examined microradiographs made from adult femora. The sample was drawn from cemeteries associated with three village sites: 1) the Meroitic (0 B.C.- A.D 350), 2) X-Group (A.D. 350-550) and 3) Christian (A.D. 550- 1300). The authors' analysis included measures of growth arrest, recovery and mineralization as well as measures of the amount of bone remodeled.

The results of this study (Martin and Armelagos, 1985) indicate as expected that young females appear to have had significant problems with bone maintenance. They suggest, as in previous studies, that young female bone loss is due to nutritional deficiencies associated with multiple pregnancies and extended lactation periods. They further suggest that bone loss is primarily the result of two distinct stresses, aging and inadequate nutrition.

Owsley (1985) measured total subperiosteal diameter, medullary width and cortical bone thickness radiographically in three Arikara Plains Village cultures in the Middle Missouri Vally of South Dakota. The samples utilized by Owsley were drawn from three variants of the Coalescent Tradition and included the Extended Coalescent (A.D. 1550-1675), the Postcontact Coalescent (A.D. 1675-1780) and the Disorganized Coalescent (A.D. 1780-1860). Archaeological evidence suggests that the subsistence base remained consistent throughout the three periods with a mixed hunting-gathering/horticulural economy. The Extended Coalescent settlement patern is characterized as exhibiting small clusters of houses. Storage pits were small and few in number, while refuse pits were typically lacking in cultural debris. The Postcontact Coalescent marks the introduction of the horse and has been termed the "heyday of the Middle Missouri Villagers" [Lehmer, 1971:136 (cited in Owsley, 1985)]. The Disorganized Coalescent represents a time of severe nutritional and disease stress in the face of climatic fluctuations and European contact. Owsley's (1985) data indicated that individuals from the Extended and Disorganized Coalescent periods exhibit thinner cortex than those individuals from the Postcontact Coalescent period. Owsley (1985) further noted that medullary width increased in the Extended and Disorganized Coalescent periods, suggesting protein as the limiting nutrient that decreased in availability. Owsley (1985) noted however, that this explanation was probably incomplete as deficiency diseases are seldom simple in causation.

Martin et al. (1987) measured cortical thickness, percent cortical area and microradiographic analysis of formation and resorption rates in African-American adults from an historic cemetery in Cedar Grove, Arkansas. Mea-

sures of percent cortical area indicated that both males and females of this group exhibited lower values than prehistoric groups which were greatly stressed with regard to nutrition (Martin and Armelagos, 1985) and contemporary individuals with significant cases of osteoporosis. The authors attribute the low values to nutrition which was substandard in terms of calcium, iron and protein, as well as infectious diseases, a rigorous lifestyle and occupationally-related degenerative skeletal problems.

CHAPTER IV

HYPOTHESIS

The preceding literature review establishes three basic premises utilized by physical anthropologists in the study of cortical bone thickness. The first of these assumes that adequate nutrition (both quantitative and qualitative) is required for the normal growth, development and maintenance of the skeletal system. The second of these essentially states that maladies resulting from nutritionally deficient diets are rarely the result of a deficiency of a single nutrient (Huss-Ashmore et al., 1982). The third premise reflected in the literature states that generally, prehistoric agricultural populations exhibit a greater loss of cortical bone than do hunter-gatherers, and that this observation reflects a more adequate diet (both quantitatively and qualitatively) utilized by the latter group.

The conclusions drawn from analyses of cortical bone area reflect directly a given population's adaptation to its environment. Following Thomas (1975), adaptation refers to the dynamic interactions between a human group and the flora and fauna available to that group. This includes the ability of the group to shift from one resource to another (either on a seasonal basis or as a result of catastrophic events), which in turn reflects the diversity and stability of the environment occupied by the group.

The skeletal sample drawn from the inhabitants of the coastal area of North Carolina during the Late Woodland (the Flynt site) does not represent a

"traditional" hunter-gatherer society, as their subsistence was attuned to estuarine resources. Some authors (e.g. Osborn, 1977; Cohen, 1977) have suggested that marine resources are inferior to terrestrial resources, both in terms of nutritional value and labor investment. However, archaeological evidence for year-round occupation (Loftfield, 1985), as well as ecological and environmental data, i.e. abundant resources (Odum and Copeland, 1974), suggests an apparently successful adaptation to the environment along the North Carolina coast during the Late Woodland. This evidence suggests that the inhabitants should compare favorably with inland agricultural groups in terms of skeletal growth, development and maintenance.

The hypothesis to be tested in this thesis is stated as follows: the diversity and abundance offered by the environment found along the North Carolina coast should have provided not only an adequate diet to the Late Woodland groups which occupied that area, but should offer some advantages in terms of adaptation as well. If, according to the anthropological and medical literature, poor or inadequate nutrition results in an abnormal thinning of the bone cortex, then the groups representing the inland Piedmont areas of North Carolina (the Donnaha/Forbush Creek sites) should exhibit a greater loss of cortical bone than the group representing the coastal region (the Flynt site).

Additionally, Ruff, (1987b; 1989) suggests that sexual dimorphism in femoral structure and associated mechanical loading tends to be more pronounced in hunter-gatherer societies than in agricultural societies, and that this sexual dimorphism reflects a greater degree of division of labor by sex. Although the coastal inhabitants represent a hunter-gatherer group, the

nature of the subsistence strategy should allow a reduced division of labor by sex with regard to activities associated with subsistence. Therefore, the coastal sample should compare favorably with the Piedmont sample in terms of femur shape and mechanical loadings.

CHAPTER V

THE SITES

ARCHAEOLOGICAL BACKGROUND OF THE NORTH CAROLINA PIEDMONT

The sequence of cultural events following the initial occupation of the Carolinas by humans was initially projected by Coe (1952). Coe's delineation concerned specifically the Piedmont of North Carolina.

North Carolina's first inhabitants probably arrived sometime around 10,000 B.C. (Woodall, 1984). Very little is known about these first inhabitants. Indeed, the only evidence of their presence is indicated by occasional surface finds of Clovis points. In the West, Clovis points date to between 10,000 and 9,500 B.C. Because of the similarity in form, those recovered from North Carolina are assumed to be similar in age.

By 8,000 B.C. the Hardaway point (Coe, 1964) appears and marks the beginning of the Archaic Period. The Archaic exhibits a possible change from primary hunting of large game animals to a seasonal cycle of hunting and gathering (Coe and Wilson, n. d.). The Archaic also exhibits the first evidence of cultural development in North Carolina, lasts until about 500 B.C. and appears to represent an 8,000 year period of cultural stability, with most sites being located in the inter-riverine uplands. One does see changes in projectile point shapes, addition and/or deletion of some tools and minor changes in site size and location during the Archaic (Woodall, 1984). Three sub-periods divide the Archaic into Early, Middle and Late phases (Coe, 1964). The Early

Archaic (ca. 8,000 B.C. to 6,000 B.C.) included the Palmer and Kirk complexes as well as the Hardaway. The Middle Archaic (ca. 6,000 B.C. to 4,000 B.C.) consists of the Stanley, Morrow Mountain and Guilford complexes. The Late Archaic is represented by the Savannah River complex which extended from about 4,000 B.C. to about 500 B.C. in some areas. By about 2,000 B.C., Piedmont sites become larger and sometimes contain bulky items such as soapstone bowls, suggesting a greater degree of permanence of sites (Woodall, 1984).

By about A.D. 0, the inter-riverine uplands are beginning to be abandoned and the larger watercourses become the predominate location of Piedmont sites. In the Great Bend area of the Yadkin Valley (the location of the and Forbush Creek sites), this shift appears to begin around A.D. 500 and be complete around A.D. 1,000. This shift may indicate a change in preference for riverine resources and/or cultivation of the soils near the river banks. With this change in the settlement pattern comes the introduction of pottery and marks the beginning of the Woodland Period (Woodall, 1984: 2).

Woodland sites are numerous in the Great Bend area of the Yadkin River (Woodall, 1984). Pottery yielded from these sites include the Yadkin series, the Uwharrie series and the Dan River series. The Yadkin series is generally tempered with sand and/or crushed rock and appears in the Piedmont about A.D. 500 (Coe, 1952). The Uwharrie series typically is tempered with crushed quartz and is found between A.D. 600 and A.D. 1,000 (Woodall, 1984). The Dan River series sees sand replacing much of the crushed quartz (Coe, 1952). This change occurs between A.D. 1,000 and A.D. 1,500 (Woodall, 1984).

The Donnaha (31 YD 9) and Forbush Creek (31 YD 1) Sites

Both the Donnaha site and the Forbush Creek site are located along a natural levee of the Yadkin River in Yadkin County, North Carolina and are situated within 10 miles of each other (Fig. V-1). The Yadkin River begins along the eastern slopes of the Blue Ridge Mountains and runs in an east-northeast direction. In the area of the Donnaha/Forbush Creek sites, the river makes a turn to the southeast. This change in direction is referred to as the Great Bend of the Yadkin. From the Great Bend, the river continues in a south-east direction until it reaches the Atlantic Ocean just south of Myrtle Beach, South Carolina (Woodall, 1984).

The river flows through resistant quartzite and granite in the mountainous portion of North Carolina resulting in a narrow, steep-sided valley. As it reaches the softer gneisses and schists of the Piedmont, broader river bottoms become characteristic. In these broader floodplains, occasional flooding results in the deposition, beyond the banks, of particles which would ordinarily be carried in suspension by the river. This yields sand deposits on the levee adjacent to the river and, farther from the banks, silt and clay deposits in the backswamp (Woodall, 1984).

The land along the Great Bend area consists of a natural levee of Buncombe loamy sand. Approximately 200 meters from the river, Congaree fine sandy loam marks the beginning of the backswamp. Heavy silt loams of the Chewacla series are found along the edge of the uplands approximately 450 meters from the river [Curle, 1962 (cited in Woodall, 1984; 6-7)].

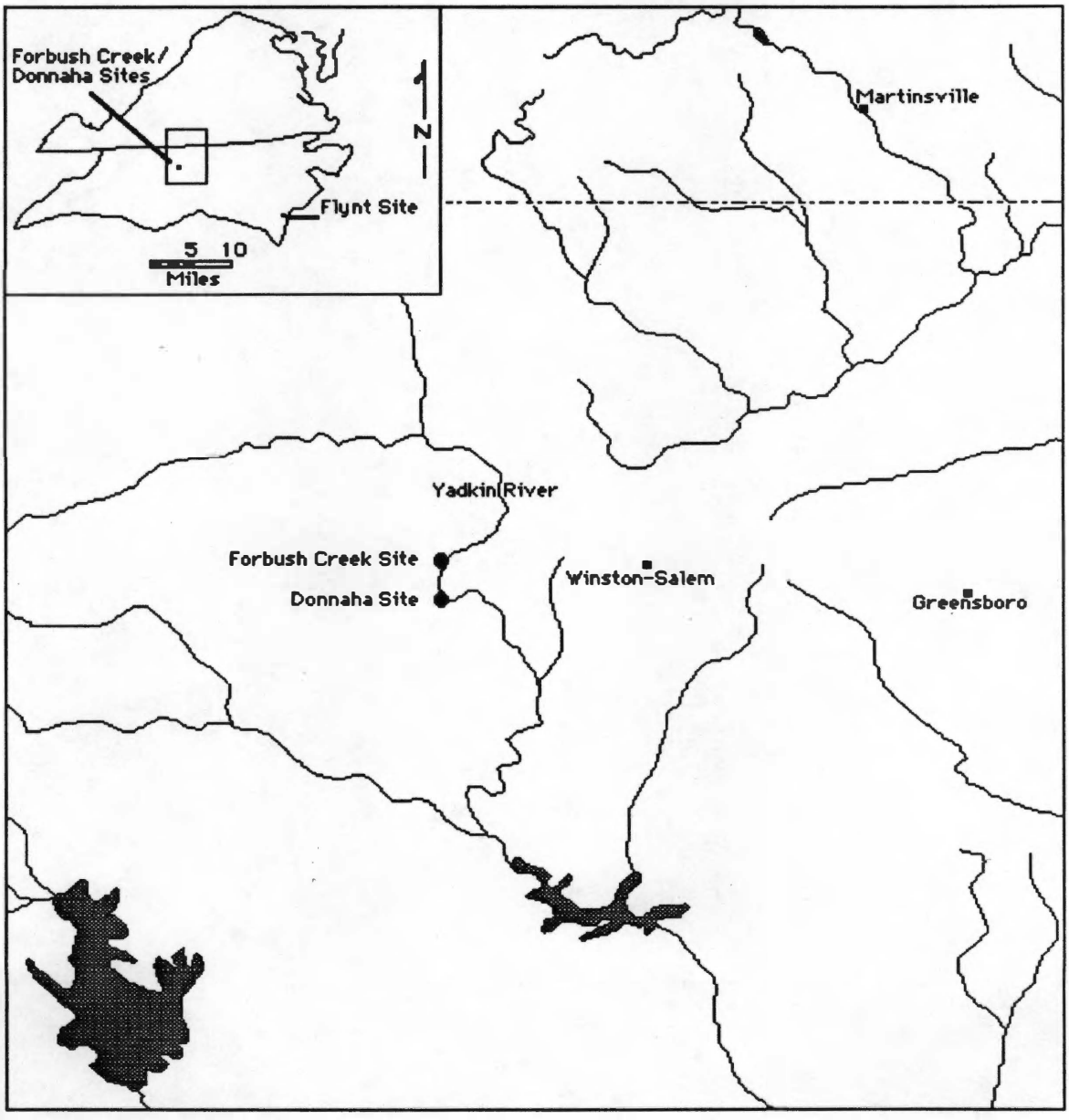


FIGURE V-1. The Forbush Creek and Donnaha sites in the North Carolina Piedmont (adapted from McManus, 1985; 4).

The content of the flora which would have been available to the inhabitants of the Great Bend area remain uncertain (Woodall, 1984). The uplands around the Donnaha site (and presumably the Forbush Creek site) most likely consisted of an oak-hickory climax forest. Present in small numbers probably were pine, tulip poplar, red gum, juniper, sassafras persimmon, black cherry, sourwood, ash, elm, holly, ironwood and dogwood [Oosting, 1942 (cited in Woodall, 1984;9)].

The floodplains probably contained an alluvial forest dominated by more water-tolerant species than those found in the adjacent uplands. However, because undisturbed climax forests in river bottoms are rare, the contents of the alluvial forest in the Great Bend remain unknown (Woodall, 1984). Oosting, [1942 (cited in Woodall, 1984;9)] found an undisturbed forest in the floodplain of the Eno River (approximately 100 miles east of the Great Bend). This forest is dominated by willow oak, red gum, swamp oak, red oak and white oak with small numbers of pine and hickory. Hard maple was abundant in the understory. Oosting lists 32 herbs in the area indicating quite a bit of diversity. Presumably, the Great Bend area would have offered a similar floral community to its inhabitants.

The occupants of the Great Bend area had access to three environmental zones from which to take game. Available from the uplands and the floodplain were white-tailed deer, elk, bear, turkey, squirrel, rabbit, opossum, skunk, fox, raccoon, beaver and terrapin. The river offered otter, mussel, turtle, frog, fish and various waterfowl (Woodall, 1984).

The Donnaha site appears to represent a year-round village whose main occupation occurred between A.D. 1,000 and A.D. 1,500. Evidence of activities

associated with hunting, plant processing, bone/wood working and tool manufacture was recovered (Woodall, 1984;103, 105). The subsistence economy was based on the hunting of land mammals, particularly deer, turkey and raccoon, the collection of fish, shellfish, wild plants and nuts, and supplemented with maize horticulture (Woodall, 1984).

The site rendered no evidence to suggest social stratification. Additionally, the population at any given time during occupation appears to be low. The Donnaha site, as well as other sites along the Great Bend seems to reflect a conservative nature when compared to contemporaneous sites elsewhere in the Southeast. No mounds were constructed, no extraordinary funerary goods are represented and the occupants continue to rely on wild foods supplemented by maize horticulture (Woodall, 1984).

The Forbush Creek site, located within ten miles of the Donnaha site, appears to represent the same culture as that of the occupants of the Donnaha site. The Forbush Creek site appears to have been occupied from approximately A.D. 1,200 to A.D. 1,500 and like Donnaha, the subsistence was based on the collection of wild plants and animals, supplemented with maize horticulture (Coe, 1972).

The tool assemblage from Forbush Creek reflects activities associated with hunting and processing of mammals, wood working and planting and harvesting corn and other cultigens (McManus 1985;36).

ARCHAEOLOGICAL BACKGROUND OF THE NORTH CAROLINA COAST

Coe's (1952, 1964) delineation of the Paleo-Indian and Archaic cultural sequences of the North Carolina Piedmont has generally been considered to

correlate well with the Coastal Plain (Loftfield, 1975). However, the Woodland Period appears along the coast much earlier than the first century A.D. Although artifacts from the Paleo-Indian and Archaic periods have been recovered, none have been recovered from site excavations, but have been entirely from surface collections. In addition these finds do not, in all probability, represent coastal sites. Due to fluctuations of sea level from glacial events, the sea stood perhaps as much as 400 feet lower during the Paleo-Indian period than it does today. Apparently, sea level rose rather rapidly throughout the Archaic period and reached a point of relative stability 4,000 to 6,000 years ago at the time of the Late Archaic (Newman, 1972; Perlman, 1980). From that period on, the rise has continued, at a slower but steadier rate. It is likely that any truly coastal Paleo-Indian, Archaic or Early Woodland sites are presently under water and perhaps as much as 40 miles offshore (Loftfield, 1986). Sites which can be said without dispute to be coastal in nature do not appear on the North Carolina coast until the Middle Woodland (Loftfield and Littleton, 1982).

Loftfield (1986) has suggested that by the Middle Woodland period, a pattern of adaptation to the coastal area was evolving based upon exploitation of estuarine resources with sites becoming less frequently located in inland areas. A slightly earlier tendency to move sites from knoll tops to bottom lands in the Late Archaic and Early Woodland periods was abandoned in favor of the coastal locations (Loftfield and Littleton, 1982).

By the Late Woodland period, essentially all sites are located adjacent to salt water, and interior sites are virtually abandoned (Loftfield, 1975; Loftfield and Littleton, 1982). Loftfield (1989) suggests that this shift in location is a consequence of the relative stabilization of the sea level, the development of

very stable resources in the shallow sounds and estuaries of the region, and the evolution of a cultural pattern of exploitation which permitted essentially sedentary occupation.

While the lithic typologies of the Piedmont seem to correlate with the Coastal Plain, the latter has a distinct ceramic tradition. South (1976) outlines the Woodland ceramic sequence for the southern coast of North Carolina, while Haag (1958) and Phelps (1983) describe the ceramic types of the northern coast of North Carolina. Onslow and Carteret counties, located on the central coast of North Carolina represent an area of overlapping ceramic traditions which are described by Loftfield (1975). South's (1976) sequence includes fiber-tempered ceramics, the Hanover sherd-tempered series, the Cape Fear sand-tempered series and the Oak Island shell-tempered series. Loftfield (1975) identifies the New River sand-tempered series of the Early Woodland. Associated with the Middle Woodland are both the clay-tempered Carteret series and the sand- or gravel-tempered Adams Creek wares. The shell-tempered White Oak series represents the Late Woodland and is associated with contact period coastal Algonquians. A second Late Woodland ware, the quartz-tempered Onslow series is associated with the inland Iroquoian speaking Tuscaroras. Phelps (1983) identifies the sand-tempered Deep Creek series of the Early Woodland, the gravel-tempered Mount Pleasant ware and the clay-tempered Hanover series of the Middle Woodland. The Late Woodland is represented by the shell-tempered Colington series and the gravel- or crushed-quartz-tempered Cashie series (Phelps, 1983). Like the wares identified by Loftfield (1975), the shell-tempered Colington is associated with Algonquian speakers while the Cashie is associated with the Iroquoians.

The Flynt Site (31 ON 305)

The Flynt site lies on the outer fringe of the Atlantic coastal plain with the Atlantic ocean lying less than two miles to the southeast (Fig. V-2). The site is adjacent to Fullards Creek, an arm of Chadwick Bay, itself an embayment of the New River and part of the long-shore sound system which is separated from the Atlantic ocean by a chain of narrow barrier islands (Loftfield, 1984).

The portion of the North Carolina coast upon which the Flynt site is located is included in the Sea Island Section of the east coast of the United States (Garrett, 1983) (Fig. V-3). The barrier islands in this section of the coast actually form a series of smaller islands or necks. The larger of these rise as much as 15 to 20 feet above sea level and often support maritime forests and freshwater ponds and/or lakes. While this chain of small islands is not considered a barrier chain per se (Adey and Burke, 1976), it has acted to reduce wave stress. This has resulted in the establishment of extensive salt marshes on the landward side of the islands as well as tidal flats and numerous meandering creeks (Loftfield, 1984).

Tides in the Sea Island Section of the coast range from four to eight feet (Garrett, 1983). The Flynt site is located along the northern boundary of the Sea Island Section, where the tides tend to be toward the lower end of the scale. The influx of the diurnal tides combined with fresh water runoff from the New River also aids in the establishment of the salt marshes (Odum and Copeland, 1974) and a diverse biotic community.

Another prominent feature of the North Carolina coast is a gently sloping continental shelf which serves to reduce wave stress (Adey and Burke, 1976) and current speeds (Perlman, 1980). Additionally, the close

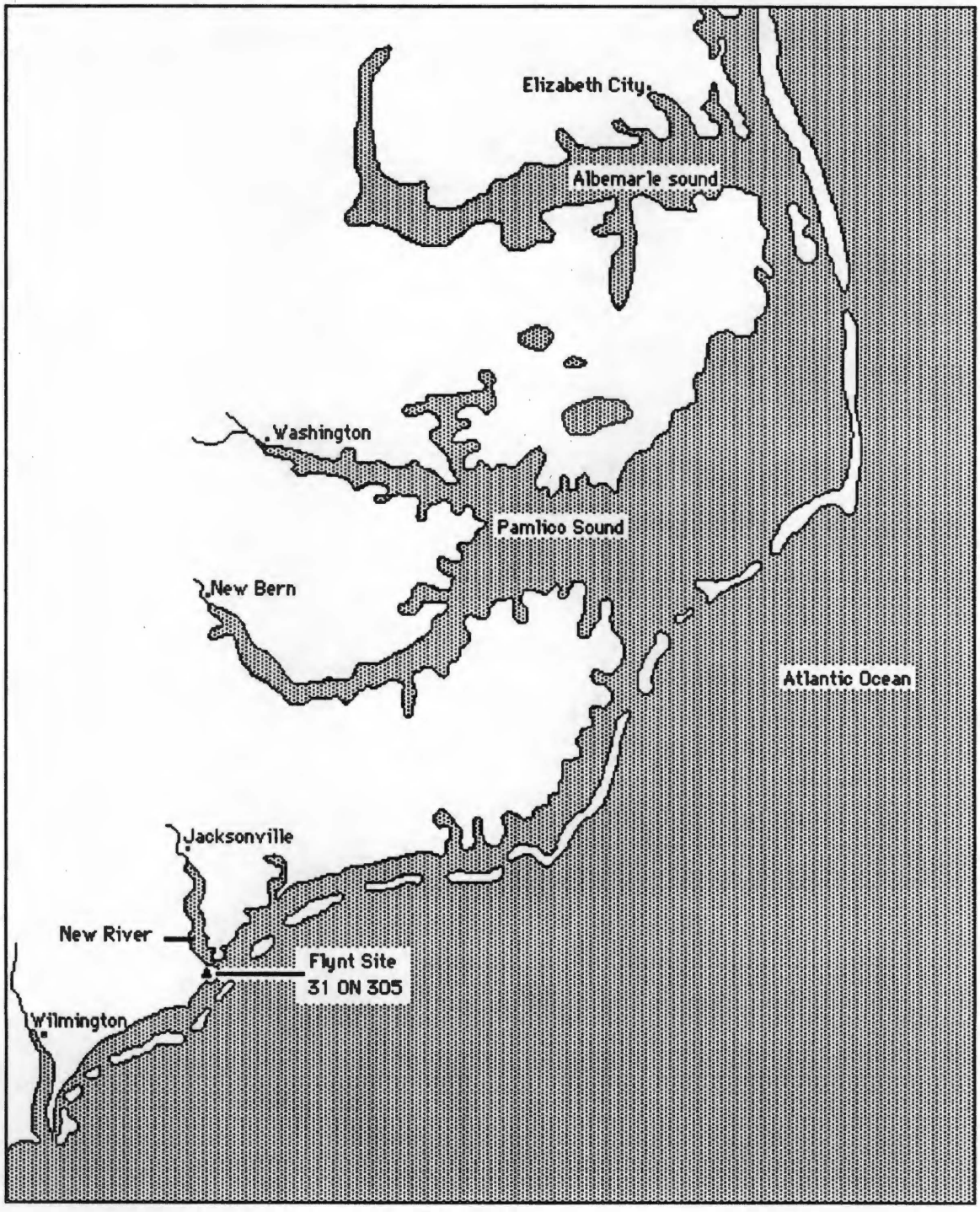


FIGURE V-2. The Flynt site on the coastal plain of North Carolina (adapted from Phelps, 1982).

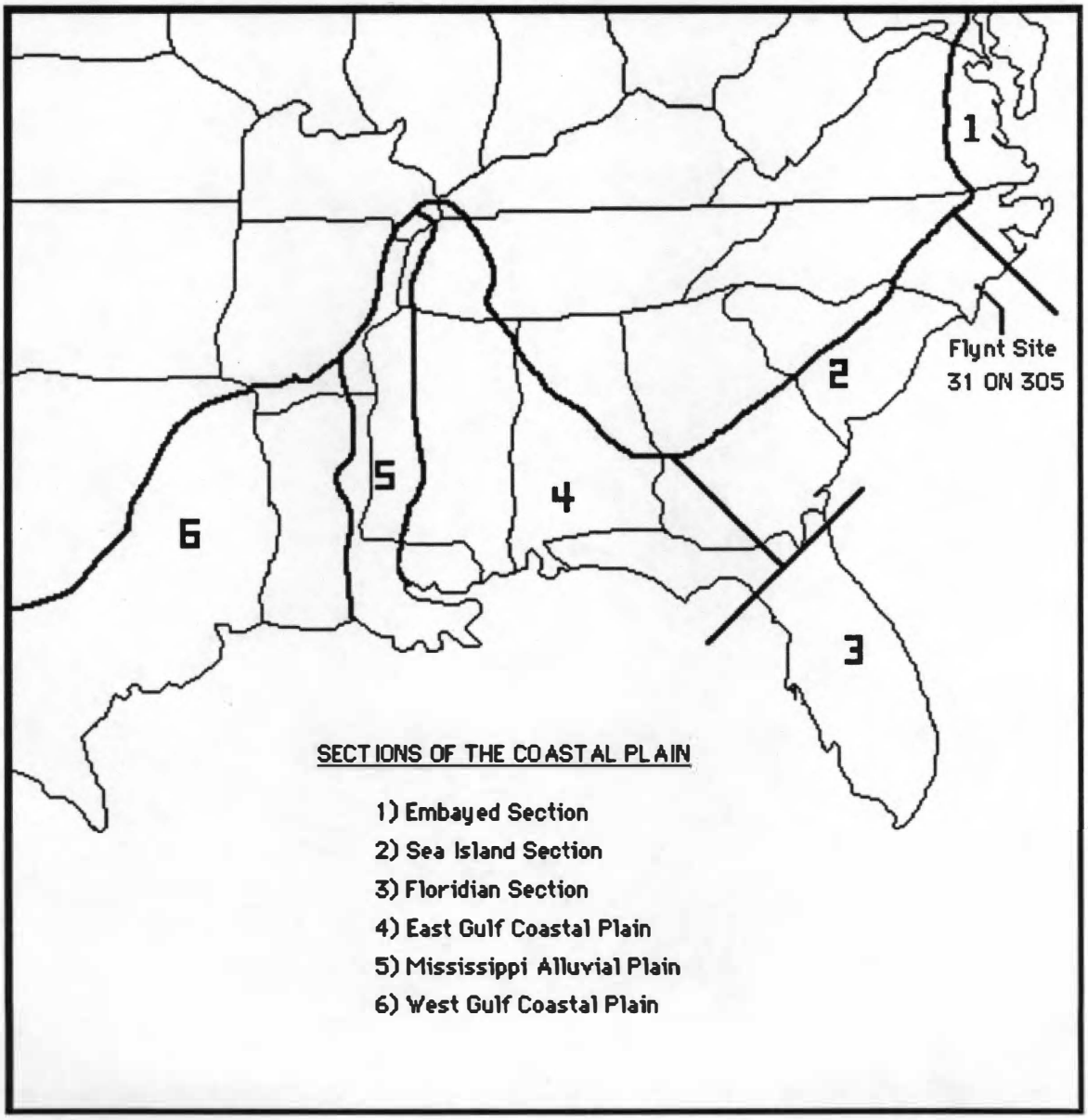


Figure V-3. The southeastern coast of the United States with sections of the coastal plain (adapted from Garrett, 1983).

proximity to the warm water of the Gulf Stream also helps to create an ideal environment for estuarine biota (Yesner, 1980). All of these features work synergistically to create a complex network of salt marshes, meandering estuarine creeks, embayments, and sounds which support an abundance of obtainable marine life.

The land upon which the site is located occupies the eastward end of the mainland of Onslow County, North Carolina. The site lies on the south side of the New River where the land is characterized as flat to gently rolling. On the north shore of the New River, the topography is occasionally quite severe with bluffs and ravines exhibiting as much as 40 feet of vertical relief within a horizontal distance of less than 100 feet (Loftfield, 1984).

The land areas in the vicinity of the site originated in a marine or coastal environment similar to that along the present North Carolina coast. Changes in sea level due to glacial activity and slight movements of the crust have caused alternating emergence and subsidence of portions of the surface at irregular intervals. When submerged, the area collected deposits of continental and marine sediments while each period of emergence resulted in erosional changes in the coastal areas. The site is located on the geological surface known as the Pamlico Terrace which generally ranges from 0 to 25 feet above sea level and extends inland approximately two miles to the Suffolk Scarp (Loftfield, 1984).

The site is underlain by several hundred feet of unconsolidated to weakly consolidated sediments ranging from Cretaceous to Miocene in age. Approximately 5 to 30 feet of recent Pleistocene sand, clay and marine shell lie immediately beneath the surface (Loftfield, 1984).

Climate in the area is warm and humid with long hot summers and short mild winters. With the waters of the warm Gulf Stream approximately 50 miles offshore, the temperatures tend to remain relatively constant.

The combination of soils and climate determine to a large extent the available plant species in the area, and to a lesser extent the fauna. The flora of the coastal region tends to be dominated by pines and other species which can tolerate both high water tables and drought, as well as occasional brush fires.

Along the coast itself, one sees the emergence of a mixed pine-hardwood forest dominated by oak and hickory interspersed with walnut. Prevailing winds generally prevent brush fires from spreading extensively and the sandy soils allow adequate drainage to support the mixed tree community.

Archaeological evidence from the Flynt site indicates that the inhabitants relied on the shallow waters of the sounds, embayments, marshes and fresh water rivers for their subsistence (Loftfield, 1986). In an analysis of remains recovered from 38 archaeological contexts and features, Mikell (1986) determined that boney fishes comprised 74.9% of the recovered assemblage. Represented in the sample were 12 taxa. Of the 12 taxa, two (sturgeon and shads/herring) are anadromous, five (eel, flounder, drum, black drum and sheepshead), are coastal ground or lower estuarine inhabitants, four (gar, catfish, bream and carp) are freshwater fish and one (mullet) is a coastal pelagic fish. No deep water specimens are represented (Mikell, 1986), indicating that only the salt marsh/estuarine system and fresh water fauna were exploited. While the sample offers no strong indicators of seasonality, all species represented are known to inhabit the coastal waters throughout the

year when winters are mild (Mikell, 1986). Additionally, Lawrence (1986) reports that oysters recovered at the site were gathered during all seasons of the year. Mammalian remains represent only 12% of the sample and other fauna comprise only 2.4% (Mikell, 1986). Other upland floral and faunal remains are virtually lacking from the site and are, in any event, overwhelmed by the importance of estuarine resources (Loftfield, 1984).

Plant foods appear to represent an under-utilized resource (Loftfield, 1986). Analysis of carbonized plant food remains recovered from the Flynt site and two other coastal North Carolina sites indicate that these remains are present in very small amounts (Glazier, 1986). Glazier (1986) reports that plant food remains represent less than 0.1% by weight of recovered carbonized materials (the remainder being wood charcoal). Domestic plant remains present were corn, sunflower and squash. Wild plant remains were restricted to acorn and hickory nuts. Hickory nuts contribute 88.4% of the plant foods which were utilized. Corn contributes 7.2% followed by acorns at 4.3%. This appears to be a "typical" plant utilization pattern for coastal North Carolina sites (Loftfield, 1975). The lack of plant food remains may be explained by several factors, including utilization away from the site, archaeological recovery techniques, differential preservation, or non-utilization by the inhabitants (Loftfield, 1986). Glazier (1986) argues for non-utilization based on the generally excellent preservation found at coastal North Carolina sites. Utilization away from the site seems unlikely when the quantity of shellfish remains is considered. It seems that if the inhabitants had been willing to transport shellfish to the site, they would have also been willing to transport plant foods

(Loftfield, 1984). Archaeological technique is probably not at fault as the flotation process yielded wood charcoal of all sizes (Loftfield, 1984).

The subsistence pattern of the inhabitants of the Flynt site appears to consist of a primary reliance on fish and shellfish, with a much smaller dependence upon land mammals and a very small reliance upon domesticated and wild plant foods (Loftfield, 1986).

Tools recovered from the Flynt site are both few in number and widely scattered in distribution. The most common tool consists of a simple stone pebble from which one to four flakes have been removed. These tools outnumber finished stone tools by nearly 100 to 1. Loftfield (1986) suggests the ubiquitous presence of these tools appears to rule out the interpretation that they represent "cobble trials" and has called them "oyster knives". He contends that they could be used for removing clams and oysters from their shells and/or scaling fish. Also recovered are whelk shells which show modification and wear on their distal ends. These tools are referred to as "whelk hoes" (Loftfield 1986), although they may serve a more useful function as tools for digging clams and oysters. Bone tools are present but very rare, as are ceramic smoking pipes. Overall the tool kits appear to be very simple, with perhaps a reliance on tools fashioned from perishable resources (Loftfield, 1986).

No structures which could suggest permanence have been located at the site. However, the suggested seasonality of the food remains (Mikell, 1986; Lawrence,1986) indicates that the site was occupied on a year-round basis. The failure to locate structures may reflect sampling bias rather than evidence indicating absence of structures.

Five radio-carbon dates have been established for the Flynt site. The earliest date is 1,140 ±60 years B.P. The latest date obtained is 760 ±70 years B.P. (Loftfield, 1984).

In summary, it appears that the inhabitants of the Flynt site relied primarily on the salt marsh/estuarine system for subsistence. This suggests that the resources were available on a year-round basis, thus allowing the establishment of a permanent, sedentary population.

CHAPTER VI

ESTUARINE RESOURCES AS A SUBSISTENCE BASE

Many variables work together to regulate those processes which in turn determine the productivity of a given coastal environment. These variables include bathymetry and slope of the continental shelf, wave stress, tidal action, topography of adjacent land, amount of fresh water runoff from inland rivers, and the presence or absence of barrier islands. Fresh water runoff has a role in determining the salinity of coastal waters as well as the establishment of salt marshes.

This chapter discusses those variables which work in concert to form ecologic zones within a given coastal region. This is followed by the presentation of an argument suggesting that the coastal region of North Carolina provided an adequate subsistence base for the Late Woodland inhabitants. Indeed, it will be argued that the subsistence base offered by the coastal environment rendered both economic and ecologic advantages to the aboringial populations.

Generally, broad shallow bathymetry and slope of the continental shelf act to create a depositional environment which tends to maintain a sediment base for the establishment of salt marshes. Coasts exhibiting high relief tend to create an erosional environment (Perlman, 1980). Local bathymetry also affects the productivity of a coastal zone by determining the degree of wave stress.

In general, the greater the degree of wave stress, the lower the productivity. However, upwelling zones such as the Pacific Coast of the United States (Perlman, 1980), and the coast of Peru (Osborn, 1977) offer exceptions to this rule.

Barrier islands enhance the productivity of a coastal zone mainly by acting to decrease wave stress. They tend to create level shallow lagoons between themselves and the adjacent land mass. These lagoons or bays are in turn conducive to the development of salt marshes (Adey and Burke, 1976).

While the productivity of a given coastal environment is the result of the synergistic effects of many variables, perhaps the most important is the establishment of salt marsh systems. Two very important factors regulating the establishment of salt marsh systems are: 1) the extent of mixing of tidal (seawater) input and fresh water runoff and 2) the speed of currents resulting from that mixing (Odum and Copeland, 1974). The mixing must be sufficient in order to maintain nutrients in suspension. However, the speed must be slow enough to allow for the formation of a sediment base upon which the marsh grasses thrive.

The salt marsh system offers several benefits to the coastal environment. Like barrier islands, the marsh absorbs the initial impact of wave stress, thus maintaining the stability of adjacent shorelines (Teal and Teal, 1969). Once established in a given locality, the marsh serves to regulate current speeds (Odum and Copeland, 1974) and maintain a depositional environment which in turn allows more marsh grasses to become established (Teal and Teal, 1969).

Perhaps the most important function of the salt marsh is the fact that it serves as a nursery and/or home for a wide variety of floral and faunal species. Clams (Mercenaria mercenaria) and oysters (Crassostrea virginica) are at the mercy of the tides and currents during their larval stages. The marsh grasses provide safety from the currents by offering areas of attachment for these species (Keck et al., 1974; Capehart and Hackney, 1989), which served as a major staple for Native Americans. Were it not for the marshes, clam and oyster larvae would have been carried to the open ocean, rendering them economically unfeasible for the Native Americans to gather.

The salt marsh also acts as a biological filter, trapping numerous varieties of phytoplankton upon which clams and oysters feed (Davis and Guillard, 1957) as well as zooplankton which attract a wide variety of finfish species (Teal and Teal, 1969).

The uses of the salt marsh or estuary are as varied as the species which inhabit it. Some species such as mullet, menhaden and shrimp live their adult lives and spawn in the open waters of the sea. However, the newly-spawned come into the estuary to feed upon its offerings until they reach maturity. Other species, for example the sea trout, come into the estuary to spawn. The young remain in the estuary until adulthood and then migrate to the open ocean. Some finfish use the estuary on a seasonal basis. Flounder and bluefish, for example, spend the winters in the open ocean and move inshore during the summer months (Teal and Teal, 1969).

Crabs as well as the clams and oysters previously mentioned spend virtually their entire life cycle in the marsh-estuarine system (Warner 1976).

Sea trout also tend to remain in the estuary throughout the year in the southern portions of the east coast (Teal and Teal, 1969).

Today, some two-thirds of the commercial catch taken from the east coast of the United States spend at least a part of their life cycle in the marsh-estuarine system (Teal and Teal, 1969). And indeed, all of the species discussed above are found in abundance at the Flynt site (Mikell, 1986).

THE EXPLOITATION OF ESTUARINE RESOURCES

The discipline of ecology has developed an optimum diet model whose basic premise states that any predator will select prey which provides the highest return for the least amount of effort and risk (Perlman, 1980). A discussion of the extent to which a population is successfully maintaining an optimum diet must address abundance, distribution, predictability and nutritional value of resources available in a given environment. Additionally, labor demands as well as the technology required to procure the available resources must be considered.

The preceding discussion establishes the fact that edible species are ubiquitous to the North Carolina coast. While the distribution of species varies from locality to locality, nearly all species which range along the east coast of the Untied States spend at least a part of their life cycles in the shallow bays and estuaries (Teal and Teal, 1969).

With regard to predictability of resources, Osborn (1977) suggests that marine environments are much less productive than terrestrial environments, stating that while the ratio of land-to-ocean surface for the world is 1:2.2, the ratio of terrestrial-to-marine net primary productivity is 4.7:1

[Pianka, 1974 (cited in Osborn, 1977)]. Osborn (1977) cites one exception to this general rule--that being the presence of upwelling currents, e.g. those found along the Pacific coast of the United States and the coast of Peru, which maintain nutrients in suspension, thereby creating a productive environment.

However, limited current speeds (Odum and Copeland, 1974) serve the same purpose along the east coast of the United States as is evidenced by the presence of extensive salt marsh systems. Further, Pietrafesa (cited in Hartline, 1980) notes that offshore waters along the southeastern coast of the United States are nearly as rich in nutrients and phytoplankton as west coast upwelling zones, as a result of activity in the adjacent warm-water Gulf Stream. Additionally, Yesner (1980) notes that coastal zones in general, serving as nursery areas for a large number of marine species, are characterized by a high biomass, i.e. abundant numbers of various species along a complex food chain. This wide range of species, hence a greater number of trophic linkages, does render the coastal environment susceptible to occasional seasonal fluctuations. However, the food web concept (Emmel, 1973) considers the total set of feeding relationships in a biotic community. With numerous inter-connected food chains, the ecosystem will remain stable even if one of the relationships is altered. For example, if the minnows of a given species become rare or absent, larger fish which feed on them are not forced to move out of the estuary. The larger fish can feed on other species in the same nutritional relationship to them as the minnows. In other words, the more components involved, the more stable the ecosystem will be. The same rule applies to the human populations which utilized the estuaries during the Late Woodland. While occasional seasonal fluctuations may suggest the po-

tential for episodes of nutritional stress, Yesner (1980) notes that the wide diversity would allow for exploitation of alternate species during seasonal fluctuations, thereby reducing the length and severity of food shortages. Additionally, coastal environments tend to exhibit less seasonal differentiation in both climate and resource availability than do terrestrial environments within the same latitude (Yesner, 1980). Moreover, shellfish, which appear to have contributed a significant amount to the subsistence base, tolerate a very high culling rate before depletion of stocks becomes effective [Shawcross 1967 (cited in Yesner, 1980)]. Indeed, even today both clams and oysters are found in abundance along the coast of North Carolina. Although pollution has resulted in the closing of vast shellfishing areas (thus reducing catches), the shellfish are still numerous.

With regard to nutritional value and labor demands, Osborn (1977) suggests that marine resources are inferior to terrestrial resources. He argues that the whitetail deer has an average weight of 63.6 kilograms and a yield of approximately 50% edible meat or 31.8 kilograms. The edible meat provides 21 grams of protein per 100 grams of meat for a total of 6.7 grams of protein from a single deer. (Klippel and Morey (1986) suggest that 52.16 kilograms is a more appropriate live weight for eastern white-tailed deer.) The procurement of an equal amount of protein would require the capture of 10,593 clams. This number of clams would yield a meat weight of 90.3 kilograms and a total weight (shells) of 408.1 kilograms. This means that clam meat yields 7.5 grams of protein per 100 grams of meat. [It should be noted that Osborn later states that clam meat yields 13 grams of protein per 100 grams of meat (Osborn, 1977: 175)]. Osborn (1977) points out that it becomes quite obvious from this argu-

ment that terrestrial hunter-gatherers can obtain more protein per unit weight, as well as have less weight to transport than their estuarine hunting-gathering counterparts. However, another perspective on this nutrition/labor comparison lends a quite different conclusion.

The actual procurement of the terrestrial versus marine resources must be considered. According to Perlman (1980), deer require an average of 10 hours per capture and an average yield of 10 pounds per hour. While shellfish (in New England bays) average only 5 pounds per hour (Perlman, 1980), the time per capture (by hand in North Carolina waters) is on the order of seconds once an established shellfish bed is located. Moreover, once a bed is located, one simply needs to return to that bed on other hunting excursions. The hunting of deer requires some organization and the game must first be located during each hunting trip. Additionally, technology, e.g. bow and arrow, and skill, e.g. stalking and shooting, are required for the procurement of deer. Further, only a small segment of the population (young adult males) is relied upon to hunt deer or other large mammals. A simple digging stick (Meehan, 1977), or modified ("digging") shells (such as those recovered from the Flynt site) are the only technologies required for the taking of clams and oysters. A knowledge of the location of shellfish beds is the extent of skill required. Shellfish gathering as a food procurement activity can be practiced by both the old and the young of both sexes. This offers two advantages to the population. First, it increases the work force, thereby decreasing the time required to obtain food and increasing time for other social functions. Secondly, the old and the young, having lower caloric requirements, are virtually able to support themselves. Meehan (1977) reports that among the Anbara of northern

Arnhem Land, Australia, an average woman can provide enough calories for herself for a day by gathering shellfish for a period of two hours. Thus, they do not act as a sump for the populations resources (Laughlin, 1968). Therefore, in coastal populations in which shellfish represent an important subsistence resource, dependency ratios tend to be lower, life expectancies higher and potential for population increase greater (Yesner, 1980).

The transportation of captured prey probably offered no problem to coastal hunter-gatherers. Thomas Hariot, in his account of travels to the North Carolina coast in 1585, writes of abundant shellfish beds and one oyster bed in particular which stretched ". . . for many miles together in length and two or three miles in breadth . . ." (deBry, 1966 ; p. 24). The inhabitants needed only to locate sites adjacent to shellfish beds, thereby reducing transportation distances to a matter of yards. Further, William Wood made observations of local inhabitants of New England opening clams upon gathering, placing the meat into bags and then discarding the shells (Wood, 1634). This practice would decrease the weight to be transported some fourfold.

The argument regarding procurement of sufficient daily protein based on protein per weight unit can be misleading. When considering the attainment of certain levels of protein daily, it becomes a question of which resources provide those levels with the least effort and least risk (Perlman, 1980: 289). According to Osborn's (1977) original figures, one clam yields approximately 8.5 grams of clam meat and 100 grams of clam meat yield 7.5 grams of protein. By this standard, a total of 533.3 grams of clam meat would be required for sufficient daily protein. This can be found in approximately 60 to 65 clams. Using Osborn's second figure (13 grams of protein per 100 grams of meat), the

amount of clam meat required becomes 307.7 grams. By this standard, only 36 clams would be required to attain a sufficient amount of protein. This number of clams could easily be harvested by any member of the population with a minimal amount of time, effort and risk. The number of oysters (yielding 10 grams of protein per 100 grams of meat) required per individual per day would be comparable to the number of clams required. While whitetail deer (and other terrestrial mammals) provide more protein per unit weight, shellfish certainly provide an adequate amount to maintain a population (Stark and Voorhies,1978).

However, attainment of a sufficient number of calories on a daily basis could present problems for a population relying strictly on shellfish. Shawcross [1967 (cited in Yesner, 1980)] suggests that the high shellfish biomass more than compensates for the higher caloric value of red meat. Huss-Ashmore et al. (1982) state that in the face of caloric deficiencies, protein can be burned to provide necessary energy. However, prolonged deficiencies in calories would result in protein deficiencies as well (Huss-Ashmore et al., 1982).

Meehan (1982) reports that among the Anbara, shellfish contributes only 6% to 17% of the calories obtained. The Anbara obtained the majority of their calories from other sources. While not assuming that the percentages of calories obtained from shellfish for the Flynt site inhabitants mirrors those of the Anbara, it seems probable that like the Anbara, other sources of calories would be necessary. Glazier (1986) reports the presence of carbonized plant remains from the Flynt site. Domesticated plants recovered include very small amounts of corn, squash and sunflower. Wild plant foods were essentially re-

stricted to very small amounts of acorn and hickory nuts. While the amount of recovered plant food remains (both domestic and wild) are very low when compared to plant food remains from inland sites (Glazier, 1986), the majority of these foods (sunflower, hickory nut and acorn) are high in calories. Additionally, the abundant fish remains recovered from the site (Mikell, 1986) would represent other sources of calories. Fish and shellfish also represent excellent sources of calcium, phosphorus, sodium, manganese, (Klippel and Morey, 1986), iodine, iron, electrolytes and other minerals.

Overall then, a diet of fish and shellfish supplemented with high calorie nuts and other plant foods appears to be adequate in terms of nutrition. Such a diet would also offer economic and ecologic advantages. All segments of the population could be employed in the gathering of subsistence resources with very little demands in terms of time and energy. Additionally the abundance and diversity of edible fauna present in the salt marsh/estuarine system would insure against the over-exploitation of particular resources.

CHAPTER VII

MATERIALS AND METHODS

DESCRIPTION OF SKELETAL MATERIALS

A sample of individuals relying primarily on marine resources as a subsistence base was selected from the coast of North Carolina. Cortical bone area was calculated from direct measurement of a cross section from the mid-shaft of the femora of these individuals. The sample (N = 13) represents the remains recovered from an ossuary at the Flynt Site (31 ON 305), a Late Woodland occupation on Chadwick Bay in Sneads Ferry, North Carolina (Fig. VI-2). As is often the case with ossuary material, some femora complete enough to determine mid-shaft (Steele, 1970) were not associated with any other skeletal remains. Therefore, age estimates for several specimens have been restricted to distinguishing between adult and sub-adult based on size and/or epiphyseal closure. These same specimens are unknown with regard to sex. However, discarding these specimens would have resulted in virtually no sample. Further, because females represent a segment of the population with known bone maintenance problems, (see e.g. Martin and Armelagos, 1985; Hummert, 1983; Martin and Armelagos, 1979; Armelagos et al., 1972; Dewey et al., 1969), observation of cortical area in females may yield an inaccurate assessment. Therefore, comparisons of the males (with fewer variables affecting cortical bone maintenance), and the populations as a whole (males and females) is considered to better reflect nutritional status with regard to cortical bone.

In order to test the hypothesis stated in Chapter IV, a sample of individuals utilizing resources other than estuarine as a mainstay of the diet was selected from the Piedmont region of North Carolina. As with the coastal sample, cortical bone area was calculated from direct measurement of a cross section from the femora of these individuals.

The Piedmont geographic region is represented by individuals from two sites. The Donnaha site (31 YD 1) and the Forbush Creek site (31 YD 9) each contribute six individuals to the study. Geographically, the two sites are located approximately 10 miles apart along the Yadkin River in Yadkin County, North Carolina (Fig. VI-1). The two sites also appear to be closely related both temporally (Late Woodland) and culturally (Woodall, 1984; McManus 1985). Due to small sample sizes, these two sites were combined to yield a total of 12 femora.

For the total sample (N = 25) no preference as to side was selected, as not all individuals are represented by both femora. Accordingly, as is often the case with anthropological studies, the author took what was reasonably available. The individuals utilized in the study are described as follows:

Donnaha/Forbush Creek Sample

Individual F1. Individual F1 is a 20-25 year old female. Age is based on the following characteristics: The anterior transverse palatal suture is obliterated (Mann et al., 1987), the third molars are erupted but show little wear and the basilar suture appears to have recently fused. Sex is based on a femoral head diameter of 42 mm, a large sciatic notch as well as a pre- and post- auricular

surface. Additionally, the mandible is rounded and the mastoids are relatively small. No pathologies are present.

Individual F2. Individual F2 appears to be an adult male. The sole aging criterion is that the teeth (including M3's) are greatly worn. Sex is based on a squared mandible, supraorbital ridges and relatively large mastoids. Signs of healing or healed porotic hyperostosis are present on the frontal bone.

Individual F3. Individual F3 appears to be an adult male. Age is based on greatly worn M3's. Additionally, both the basilar and anterior transverse palatal sutures are obliterated (Mann et al., 1987). Sex is based on supraorbital ridges, squared mandible, large mastoids and the zygomatic arch extending posteriorly beyond the external auditory meatus. Resorption of both the mandible and maxilla as well as calculus on the upper right M1 suggests the presence of periodontal disease (Ortner and Putschar, 1981).

Individual F4. Individual F4 appears to be an adult female. Age is based on a closed basilar suture, an obliterated anterior transverse palatal suture and greatly worn dentition. Sex is based on a femoral head diameter of 41 mm, a large sciatic notch and a rounded mandible. Calculus on an upper molar (only tooth present) suggests periodontal disease (Ortner and Putschar, 1981); however, the maxilla is too badly eroded to make a diagnosis.

Individual F5. Individual F5 appears to be a 20-25-year-old female. Age is based on obliteration of half of the anterior transverse palatal suture and re-

cently closed epiphyses of the long bones. Sex is based on small mastoids, parietal bossing and a general gracile appearance. Dental wear is moderate and no pathologies are present.

Individual F6. Individual F6 appears to be an "older" adult male. The anterior palatal suture is obliterated and the M3's are badly worn. Sex is based on the presence of supraorbital ridges, large mastoids, large area of attachment of nuchal muscles and a squared mandible. No pathologies are present.

Individual D1. Individual D1 appears to be an adult female aged at 30-40 years. This individual exhibits advanced dental wear as well as numerous caries and some antemortem tooth loss. Also noted are resorbed cranial lesions which may have been associated either with an as yet undiagnosed disease or a systemic infection resulting from dental abscesses leading to the antemortem tooth loss (Weaver, 1984).

Individual D2. Individual D2 appears to be an adult male aged at greater than 40 years. No pathologies are present.

Individual D6. Individual D6 appears to be a male between 20 and 25 years at death. This individual also showed numerous caries, particularly in the premolar and molar regions. Moderate dental wear is also noted. The fragmentary nature of the skeleton makes further statements regarding the health status difficult (Weaver, 1984).

Individual D7. Individual D7 appears to be an adult female aged at greater than 30 years at death. Dental wear is advanced and the molar regions are characterized by numerous caries. The right radius has been fractured and healed resulting in a slight torsion of the shaft. The right ulna may have been fractured as well (Weaver, 1984).

Individual D9. Individual D9 appears to be an adult female aged at greater than 40 years. No pathologies are present.

Individual D10. Individual D10 appears to be an adolescent female. Dental caries are already present in the upper and lower molars. A supernumerary tooth is present in the upper incisors.

Skeletal Assessment of the Donnaha/Forbush Creek Sample

In general, the pattern of pathologies observed in the Donnaha/Forbush Creek individuals appears to indicate a population under severe nutritional and disease stress. Dental disease is prevalent and the indicators of chronic anemias are present.

The advanced wear of the dentition indicates a tough, gritty diet probably high in carbohydrates (Weaver, 1984). Brothwell (1981) notes that a high degree of dental wear is common in populations relying on agriculture as a subsistence base. However, Weaver (1984) suggests that a diet consisting of gathered wild plant foods which were processed by grinding would contain a high proportion of grit, and subsequently result in a high degree of dental wear. The archaeological evidence indicates that the individuals occupying

the Donnaha site probably relied on a diet typical of hunter-gatherers in the Late Woodland Piedmont supplemented by maize agriculture (Woodall, 1984). Regardless of the source of food, the ubiquitous dental caries as well as dental abscesses resulting in antemortem tooth loss suggest a diet high in carbohydrates (Wing and Brown, 1979).

Porotic hyperostosis occurs in high frequencies among the Donnaha individuals indicating chronic nutritional deficiencies. Additionally, the dental abscesses led to two cases of chronic osteomyelitis (Weaver, 1984).

Further, an analysis of the carbon 13 to carbon 12 ratio in a small sample of individuals from the site indicates a contribution to the diet of C4 plants ranging from 26% to 59% (Weaver, 1984). Maize is the most common C4 plant in North America.

In summary, the analysis of the skeletal remains from the Donnaha/Forbush Creek and Forbush Creek sites indicates a population experiencing severe nutritional stress. Though the dietary stresses may have been seasonal, the overall pattern of pathologies observed strongly suggests that such stresses had a deleterious effect upon the population (Weaver, 1984).

Flynt Site Sample

Individual SF 1. Individual SF 1 is represented only by a left femur. No other skeletal elements can be associated with this femur. Further, the majority of the femoral head is missing, making an estimation of sex impossible. The femur was that of an adult. No pathologies are present.

Individual SF 2. Individual SF 2 appears to be a male aged at 24-35 years. An age of 24-26 is indicated by the pubis, while dental wear suggests an age of approximately 25-35 years. Bogdan and Weaver, (1989) suggest that this individual was in his late twenties at death. Sex is based on a femoral head diameter greater than 45 mms. Enamel hypoplasic defects indicate this individual suffered two stress episodes at age 4 and 5 (Bogdan and Weaver, 1989). The femur utilized in this research shows no pathologies.

Individual SF 3. Individual SF 3 appears to be an adult female. Age is based on epiphyseal closure. Sex is based on femoral head diameter of less than 42 mms. The left tibia exhibits a Harris line in the cortical bone approximately 6 cms from the condyles. No other pathologies are present (Bogdan and Weaver, 1989). The femur utilized in this research shows no pathologies.

Individual SF 4. Individual SF 4 appears to be an adult male. Age is based on epiphyseal closure. Sex is based on traits of the innominates (Bogdan and Weaver, 1989) and includes large and deep obturator foramena, sharp angles of the greater sciatic notch, curved sacrum and general robusticity (Bass, 1971). The characteristics of the pathologies, as well as their distribution suggest that a treponemal infection probably affected this individual (Bogdan and Weaver, 1989). No pathologies are present on the femur utilized in this research.

Individual SF 5. Individual SF 5 is represented by a right femur. No other skeletal elements can be associated with this femur. Epipheseal closure indi-

cates that this individual was an adult at death. Sex can not be estimated. No pathologies are present.

Individual SF 6. Individual SF 6 appears to represent the remains of an adult female. Age is based on epiphyseal closure. The femur and tibia are gracile and measurements of the femur Bass, 1971) indicate that this individual is probably a female (Bogdan and Weaver, 1989). There is periostitis, swelling and subperiosteal spiculation at the distal lateral end of the tibia, periostitis on the shaft and spiculation at the lateral proximal end of the shaft. These pathologies suggest a treponemal infection (Bogdan and Weaver, 1989). No pathologies are present on the femur utilized in this research.

Individual SF 7. Individual SF 7 appears to be an adult male. Age is based on epiphyseal closure and general size of the elements present. Sex is based on traits of the innominate (Bass, 1971) and include a deep acetabulum, non-elevated auricular surface, a sharp angle of the greater sciatic notch and general robusticity (Bogdan and Weaver, 1989). The tibia exhibits periostitis in the middle part of the shaft and at the articular surface for the fibula. Some lateral torsion is present in the anterior tibia shaft. Both patellae and the left first cuniform show exostosis. The navicular experienced probable avascular necrosis. The periostitis may indicate the beginning of bone involvement by treponemal infection. The tibial torsion may have resulted from alterations in gait due to the pain of the infection. The exostoses probably indicate arthritis and the necrosis present in the navicular may represent trauma or local ef-

fects of the treponemal infection (Bogdan and Weaver, 1989). The femur utilized in this research shows no pathologies.

Individual SF 8. Based upon epiphyseal closure, this individual appears to be between 14 and 19 years of age. No material to aid in the estimation of sex was available for this specimen. No pathologies are present.

Individual SF 9. Femoral head diameter is greater than 45 mm, suggesting that this specimen is a male. Epiphyseal closure indicates an adult. The vertabrae, ribs, humerus and radii exhibit cortical destruction and cavitation. The ulna is likewise affected and shows some medullary cavity obstruction. The long bones are affected at the diaphyses and some metaphyses by cortical destruction as well as radial subperiosteal spiculation. The clavicle is swollen and exhibits the same spiculation at the acromial end. Diagnosis excludes trauma, hematogenous osteomyelitis, myeloma, carcinoma, osteosarcoma, mycotic and mycobacterial infection. The pathologies observed suggest a treponemal infection, probably of the endemic type (Bogdan and Weaver, 1989). The femur utilized in this research shows no pathologies.

Individual SF 10. Individual SF 10 is represented by a right femur. No other elements can be associated with this femur. Epiphyseal closure and general size indicate that this individual was an adult at death. Sex can not be estimated. No patholgies are present.

Individual SF 11. Individual SF 11 is represented by by a right femur. No other skeletal elements can be associated with this femur. Epiphyseal closure and general size indicate that this individual was an adult at death. Sex can not be estimated. No patholgies are present.

Individual SF 12. Individual SF 12 appears to represent the remains of an adult male. Age at death is estimated at between 25 and 35 years, and is based on the pubic symphysis (Suchey et al., 1986). The innominate exhibits male characteristics including a narrow pubic symphysis, deep acetabulum, narrow greater sciatic notch and a non-elevated auricular surface (Bogdan and Weaver, 1989). The proximal end of the right tibia exhibits joint destruction and perarticular bony build up, suggesting a possibility of Charcot joint. It is the result of uncontrolled mechanical abuse in the absence of normal pain and position sensations, combined with abnormal neurovascular control of circulation. One of the most common causes of this pathology is *tabes dorsalis*, a late manifestation of neurosyphilis (Bogdan and Weaver, 1989). The femur utilized in this research shows no pathologies.

Individual SF 13. Individual SF 13 appears to represent the remains of an adult. Age is based on the size of the skeletal elements present. Sex can not be estimated for this individual. There is swelling on the dorsal side of the tibia and on the left femur on the dorsal side at the distal shaft. There is also evidence of periostitis at both of these locations. This could all be the result of a general infection in the left leg. The swelling in the tibia resembles that seen

in local osteomyelitis or treponemal infection. It should be noted that the left femur was utilized in this research (Bogdan and Weaver, 1989).

Skeletal Assessment of the Flynt Site Sample

There is strong evidence for a relatively high frequency of treponemal infection in the Flynt site skeletal material (Bogdan, 1989; Bogdan and Weaver, 1989). The effects which a specific treponemal infection might have on the remainder of the skeleton in general and on cortical bone thickness throughout the skeleton in particular remain unknown. Possible effects will be addressed later.

In general, however, the pattern of pathologies seen gives little indication of either severe or chronic episodes of nutritional stress. In summary then, the skeletal remains from the Flynt site appear to represent a population which was well-adjusted with regard to dietary health.

METHODS

Each femur was sectioned 1.5 cms proximal to the mid-point of the diaphysis using a standard fine toothed (32 teeth per inch) hand-held hack saw. A second cut was then made 1.5 cms distal to the mid-point of the diaphysis, yielding a three cm section removed with the mid shaft intact. Mid shaft was determined by the midpoint of the maximum femur length (Bass, 1971). In the case of incomplete femora, maximum length was determined following Steele (1970).

In some cases, the medullary cavity was filled with compacted sand and/or soil. The debris was removed in order to better discern the small inter-

stices formed by trabecular bone along the endosteal surface. Low water pressure was found to be adequate in removing the soils and sands.

Preservation of the Flynt site (coastal) material was very good and no problems were encountered in the removal of the bone sections. Preservation of the Donnaha/Forbush Creek sites (Piedmont) was not very good. In this case, a slower cutting action was required in combination with dripping cold tap water on the bone as well as periods of rest to allow the bone to cool.

Measures of cortical area were then taken. Cortical area measurements are a direct function of both cortical thickness and periosteal diameter, allowing a more accurate assessment than simple measures of cortical thickness. This is true because the periosteal diameter increases with age. Therefore, the amount of cortical area can be maintained even with a decrease in cortical thickness. Measurements of cortical area yield a picture of the entire cross sectional cortex, not just an average of several pre-determined points (Martin et al., 1979).

Cortical area was determined by placing a 2 mm transparent (mylar) grid on the proximal surface of the bone section (Sedlin et al., 1963) (Fig. VII-1). The number of line-intersects over bone tissue was then determined using a 10X dissecting microscope in order to reduce counting error. The final count of line-intersects for each section was determined by averaging the number of intersects of two separate randomly placed using the formula:

$$\text{area} = i(a)/ T_i$$

where i equals the number of line intersects over cortical bone tissue, a equals the total grid area and T_i equals the total possible number of intersects within the grid area (Carlson et al., 1976; VanGerven, 1973). Percent cortical area was

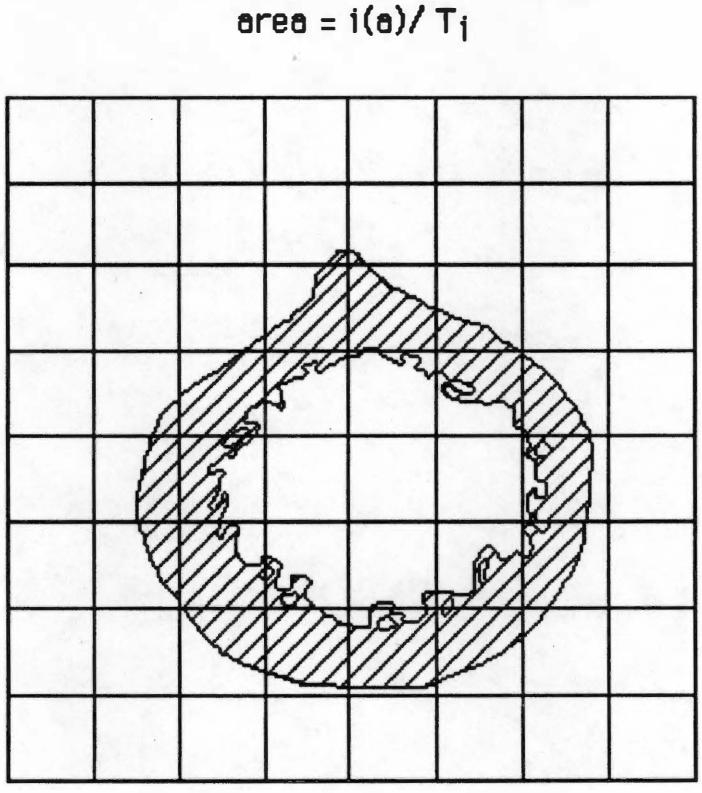


Figure VII-1. Diagram of the grid intersection count method used to determine cortical area.

computed by dividing the cortical area by the area of the total cross section (medullary cavity and cortex) (Martin et al.,1985).

The sample was divided into two groups: 1) those specimens from the coastal Flynt site and 2) those specimens from the Piedmont Donnaha/Forbush Creek sites. The specimens from each of the two groups were further divided into male and female subgroups. Student's *t* -tests were then applied to calculate the difference between the means of the groups as a whole as well as the sex-specific means of the groups.

Additionally, subperiosteal diameters were taken in both anteroposterior and mediolateral directions. An index indicating shape, i.e. circularity was derived by dividing the mediolateral diameter by the anteroposterior diameter.

As with the analysis of percent cortical area, the sample was divided into the coastal and Piedmont groups. The two groups were again separated into male and female subgroups. Student's *t* -tests were then applied to calculate the difference between the means of the groups as a whole as well as the sex-specific means of the groups.

Ruff (1987b: 1989) suggests that hunter-gatherer groups typically display a greater degree of sexual dimorphism with regard to femur structure and mechanical loadings. The dimorphism generally appears with the males tending toward a greater anteroposterior loading. This has been interpreted as indicating that males, in a hunter-gatherer society, generally experience more mechanical loading (as a result of travel associated with hunting excursions) than females.

CHAPTER VIII

RESULTS AND DISCUSSION

The measures of cortical bone area and percent cortical bone area for males and females combined (as well as those individuals for which sex could not be determined) from the Flynt site (N = 13) and the Donnaha/Forbush Creek sites (N = 12) are presented in Tables 1 and 2 respectively. The mean percent cortical bone area for the combined sexes from the Flynt site is 75.53, while that of the combined sexes from the Donnaha/Forbush Creek sites is 65.52. Student's *t*-test (alpha = .005) indicates that the individuals representing the Flynt site exhibit significantly more percent cortical bone area than those individuals from the combined Donnaha/Forbush Creek sites. The data for the males and females combined appear to support the hypothesis that the coastal inhabitants enjoyed a more nutritious diet than did the inhabitants of the Piedmont region.

The measures of cortical bone area and percent cortical bone area for males from the Flynt site and the Donnaha/Forbush Creek sites are presented in Tables 3 and 4 respectively. Like the results of the combined sexes, the males from the Flynt site (N = 6) exhibit significantly more percent cortical bone area than males from the Donnaha/Forbush Creek sites [N = 5 (alpha = .005)]. The males from the Flynt site have a mean percent cortical bone area of 77.92. The males from the Donnaha/Forbush Creek sites have a mean percent cortical bone area of 67.42.

TABLE 1

Percentage of cortical bone for combined sexes from the Flynt site.

SPECIMEN	SIDE	AGE (yrs)	SEX	CORTICAL AREA (mm^2)	TOTAL AREA (mm^2)	% CORTICAL AREA
SF 1	L	adult	?	280.02	390.53	71.71
SF 2	R	24-26	M	385.85	450.47	85.65
SF 3	R	adult	F	213.53	322.16	66.28
SF 4	L	adult	M	339.02	475.75	71.26
SF 5	R	adult	?	419.56	488.86	85.82
SF 6	L	adult	F	296.88	421.43	70.44
SF 7	L	adult	M	432.67	565.66	76.49
SF 8	L	14-19	?	277.21	362.43	76.48
SF 9	R	adult	M	408.32	496.36	82.26
SF 10	L	adult	?	260.35	354.00	73.54
SF 11	R	adult	?	368.05	454.21	81.03
SF 12	R	25-35	M	286.58	404.58	70.83
SF 13	L	adult	M	383.04	546.93	70.03
MEAN				334.70	441.03	75.53
SD				69.85	73.99	6.36

TABLE 2

Percentage of cortical bone for combined sexes from the Donnaha/Forbush Creek Sites

SPECIMEN	SIDE	AGE (yrs)	SEX	CORTICAL AREA (mm^2)	TOTAL AREA (mm^2)	% CORTICAL AREA
D1	l	25-40	F	243.75	412.07	59.15
D2	L	40+	M	293.13	461.70	63.49
D6	R	25-30	M	310.92	450.47	69.02
D7	L	30+	F	252.86	366.18	69.05
D9	L	40+	F	243.50	515.09	47.27
D10	L	14-17	F	170.45	241.62	70.54
F1	L	20-25	F	313.73	461.71	67.95
F2	R	40+	M	283.77	395.21	71.80
F3	R	40+	M	281.89	442.98	63.64
F4	L	40+	F	239.75	378.35	63.38
F5	L	20-25	F	306.24	426.12	71.87
F6	L	40+	M	306.24	442.98	69.13
MEAN				270.52	416.20	65.52
SD				42.19	68.42	6.97

TABLE 3

Percentage of cortical bone in males from the Flynt site.

SPECIMEN	AGE (YRS)	CORTICAL AREA (mm^2)	TOTAL AREA (mm^2)	% CORTICAL AREA
SF 2	24-26	385.85	450.47	85.65
SF 4	adult	339.02	475.75	71.26
SF 7	adult	432.67	565.66	76.49
SF 9	adult	408.32	496.36	82.26
SF 12	25-35	286.58	404.58	81.03
SF 13	adult	383.04	546.93	70.83
MEAN		372.58	489.95	77.92
SD		52.33	60.11	6.08

TABLE 4

Percentage of cortical bone in males from the Donnaha/Forbush Creek sites.

SPECIMEN	AGE(yrs)	CORTICAL AREA (mm^2)	TOTAL AREA (mm^2)	% CORTICAL AREA
D 2	40+	293.13	461.70	63.49
D 6	25-30	310.92	450.47	69.02
F 2	40+	283.77	395.21	71.80
F 3	40+	281.89	442.98	63.64
F 6	40+	306.24	442.98	69.13
MEAN		295.19	438.66	67.42
SD		13.04	25.47	3.68

The measures of cortical bone area and percent cortical bone area for females from both the Flynt site and the Donnaha/Forbush Creek sites are presented in Tables 5 and 6 respectively. The sample size from the Flynt site (N = 2) is too small for statistical analysis. However, the mean percent cortical bone area for the Flynt site females (68.30) is greater than that of the Donnaha/Forbush Creek site females [64.17 (N = 7)]. In fact, the females from the Flynt site exhibit a greater percent cortical bone area than the males from the Donnaha/Forbush Creek sites.

It has been demonstrated that pregnancy and lactation in females can create problems with skeletal maintenance, as a marked amount of nutrients are utilized in the growth and development of the fetus. This is especially so in the face of nutritional stress (see e.g. Martin and Armelagos, 1985; Hummert, 1983; Martin and Armelagos, 1979; Armelagos et al., 1972; Dewey et al., 1969). Because of the bone maintenance problems known to occur in females, observation of cortical area in females may yield an inaccurate assessment. Therefore, comparisons of the males (with fewer variables affecting cortical bone maintenance), and the populations as a whole (pooled males and females) may yield a more accurate assessment of nutritional status with regard to cortical bone maintenance.

Table 7 presents comparisons of percent cortical area between the Flynt site and the Donnaha/Forbush Creek sites. Differences in percent cortical bone area for the sexes combined and for the males are highly significant at the .005 level (t-tests), with the coastal samples exhibiting a greater percentage. These data suggest that the coastal inhabitants maintained a higher health status than the Piedmont inhabitants with regard to nutrition.

TABLE 5

Percentage of cortical bone in females from the Flynt site.

SPECIMEN	AGE (yrs)	CORTICAL AREA (mm^2)	TOTAL AREA (mm^2)	%CORTICAL AREA
SF 3	adult	213.53	322.16	66.28
SF 6	adult	296.88	421.43	70.44
MEAN		255.20	371.79	68.3
SD		58.93	70.19	2.94

TABLE 6

Percentage of cortical bone in females from the Donnaha/Forbush Creek sites.

SPECIMEN	AGE (yrs)	CORTICAL AREA (mm^2)	TOTAL AREA (mm^2)	% CORTICAL AREA
D 1	25-40	243.75	412.07	59.15
D 7	25-40	252.86	366.18	69.05
D 9	40+	243.50	515.09	47.27
D 10	14-17	170.45	241.62	70.54
F 1	20-25	313.73	461.71	67.95
F 4	40+	239.75	378.35	63.38
F 5	20-25	306.24	426.12	71.87
MEAN		252.90	400.17	64.17
SD		47.76	86.19	8.65

TABLE 7

Means and Standard Deviations of Percent Cortical Bone Area for the Flynt Site and Donnaha/Forbush Creek Sites

	Flynt			Donnaha/Forbush Creek				
	n	% Cortical Area	SD	n	% Cortical Area	SD	t	P
Sexes Combined	13	75.53	6.36	12	65.52	6.97	-4.97	.005
Males	6	77.92	6.08	5	67.42	3.68	-5.77	.005
Females	2	68.30	2.94	7	64.17	8.65	-1.28	.100

Nutritional deficiency diseases are seldom simple in causation. Rarely is a single nutrient deficiency the sole cause for a deficiency disease. Frequently, disease is the result of synergistic actions of several nutrient deficiencies (Huss-Ashmore et al. (1982). However, calcium may be the primary factor involved in the differences in cortical bone area between the coastal and Piedmont groups. Sandler et al. (1985) suggest that low calcium intake during childhood and adolescence can have an adverse effect on skeletal maintenance throughout life. The coastal population undoutedly obtained adequate calcium from the shellfish which were the primary component of their diet. Calcium (or a lack thereof) among the Piedmont inhabitants seems the most likely area of discrepancy between the two diets.

The coastal females exhibit a significantly greater percent cortical area than the females from the Piedmont region (.10; t-test). However, the coastal sample of females (n = 2) is too small to obtain reliable statistical data.

The Flynt site inhabitants also compare favorably with other groups in terms of percent cortical bone area (Table 8). They exhibit a significantly higher percent cortical area than those individuals of the X-Group (A.D. 350-550) from Sudanese Nubia (Martin and Armelagos 1979). The X-Group population represents an example of intensive agriculturalists, relying primarily on grains such as millet, sorghum and barley (Martin and Armelagos 1985) and appear to be have experienced skeletal maintenance problems characteristic of other agricultural populations. The individuals from the Donnaha/Forbush Creek sites exhibit a percent cortical area value which is significantly lower than the mean for the X-Group.

TABLE 8

Comparison of Percent Cortical Area (combined sexes) between the Flynt Site, Donnaha/Forbush Creek Sites and other studies

	Flynt	Don/For Crk	X-Group [1]	Cedar Grove [2]
Mean	75.53	65.52	71.00	68.21
SD	6.36	6.97	0.73	7.0
n	13	12	63	29

[1] Martin and Armelagos (1979), [2] Martin et al. (1987)

The individuals representing the Flynt site also compare favorably (though not significantly) with African-American adults recovered from an historic cemetery in Cedar Grove, Arkansas (Martin and Armelagos 1987). Martin and Armelagos (1987) state that both males and females of this group exhibit lower percent cortical area values than prehistoric groups which were greatly stressed with regard to nutrition. The Donnaha/Forbush Creek sample exhibits a somewhat lower mean percent cortical area than the Cedar Grove African-American group. This is particularly interesting in that Martin and Armelagos (1987) suggest that calcium deprivation among the Cedar Grove African-American group may be one of the primary causative factors of the decreased percent cortical area.

Chapters V and VI clearly demonstrate that the inhabitants of the North Carolina coast experienced a quite different environment than the inhabitants of the North Carolina Piedmont and that the resultant subsistence strategies differed dramatically. Additionally, it seems reasonable to assume that labor demands required for the procurement of food probably differed greatly between the two groups. The evidence presented and discussed in chapter VI suggests that labor demands on the inhabitants of the coastal region should have been somewhat less than those imposed upon the inhabitants of the Piedmont region. Additionally, the archaeological, ecological and ethnohistoric data suggest that division of labor should have been less marked in the coastal population than in the Piedmont group.

Ruff (1987b; 1989:12) suggests that cross-sectional shape variation in the lower limbs is partially function-related, and that sexual dimorphism can result from sex differences in activities. However, the degree of sexual dimor-

phism varies according to subsistence strategy. Specifically, male lower limb bones are less round and tend to be more elongated anteroposteriorly and "flattened" in a mediolateral direction (especially in the mid-distal femoral shaft), indicating an adaptation to relatively greater anterior-posterior bending. Ruff and Hayes (1983a) suggest that the anterior-posterior bending adaptation conforms well with generally accepted views on the changes in loading of the hip brought about by the move from quadrupedal to bipedal locomotion during early hominid evolution [Lovejoy et al., 1973 (cited in Ruff and Hayes, 1983a)], and may indicate relatively greater anterior-posterior bending moments about the knee. Accordingly, this sex difference is prominent in hunter-gatherers and tends to decrease in agriculturalists. The degree of sexual dimorphism in this structural feature appears to be related to division of labor (primarily in subsistence procurement activities), with ". . . greater mobility and long distance travel by hunter-gatherer males leading to greater anteroposterior/mediolateral bending strength, and with sexual dimorphism in this feature declining with the adoption of more sedentary (and less sex-specific) behavioral patterns" (Ruff, 1989:12).

Measures of anteroposterior diameter and mediolateral diameter for the combined sexes from the Flynt site and the Donnaha/Forbush Creek sites are listed in Tables 9 and 10 respectively. Comparisons between the males from each group are presented in Table 11. The coastal group exhibits a larger diameter (both anteroposteriorly and mediolaterally) as well as a more circular shape. However, none of the differences are significant. Comparisons between the females from each group are presented in Table 12. As in the comparisons between males, the females exhibit larger (though non-significant)

TABLE 9

Total Subperiosteal Diameters for the Combined Sexes from the Flynt Site

SPECIMEN	SIDE	AGE	SEX	A-P (mm)	M-L (mm)	INDEX
SF 1	L	adult	indet.	29.79	24.61	.826
SF 2	R	24-26	M	29.26	23.11	.790
SF 3	R	adult	F	27.94	22.86	.818
SF 4	L	adult	M	29.46	26.03	0.830
SF 5	R	adult	indet.	30.17	24.28	0.804
SF 6	L	adult	F	25.09	25.45	1.010
SF 7	L	adult	M	33.24	26.39	0.794
SF 8	L	14-19	indet.	24.13	23.21	0.961
SF 9	R	adult	M	30.71	27.94	0.909
SF 10	L	adult	indet.	27.96	21.08	0.754
SF 11	R	adult	indet.	29.43	23.19	0.788
SF 12	R	25-35	M	24.51	24.61	1.004
SF 13	L	adult	M	28.52	29.34	1.030
MEAN				28.47	24.78	0.874
S D				2.60	2.25	0.097

abbreviations: A-P = anteroposterior diameter; M-L = mediolateral diameter; Index = "shape" index calculated as M-L/A-P (ratios closer to 1 = more circular).

TABLE 10

Total Subperiosteal Diameters for the Combined Sexes from the Donnaha/Forbush Creek Sites

SPECIMEN	SIDE	AGE	SEX	A-P (mm)	M-L (mm)	INDEX
D 1	L	25-40	F	25.04	25.04	1.000
D 2	L	40+	M	30.43	24.61	0.809
D 6	R	25-30	M	30.50	28.29	0.927
D 7	L	30+	F	25.12	24.36	0.970
D 9	L	40+	F	29.61	25.90	0.875
D 10	L	14-17	F	23.29	19.25	0.826
F 1	L	20-25	F	22.93	27.81	0.824
F 2	R	40+	M	26.34	22.40	0.850
F 3	R	40+	M	27.18	23.03	0.847
F 4	L	40+	F	24.94	25.24	0.988
F 5	L	40+	F	28.47	21.87	0.768
F 6	L	20-25	F	29.41	22.45	0.763
MEAN				26.94	24.18	0.904
SD				2.71	2.56	0.127

abbreviations: A-P = anteroposterior diameter; M-L = mediolateral diameter; I = "shape" index calculated as M-L/A-P (ratios closer to 1 = more circular).

TABLE 11

Means and Standard Deviations of Subperiosteal Diameters for Males from the Flynt Site and the Donnaha/Forbush Creek Sites

	Flynt			Donnaha/Forbush Creek				
	n	Mean (mm)	SD	n	Mean (mm)	SD	t	P
A-P	6	29.28	2.86	5	28.77	1.90	0.33	___
M-L	6	26.23	2.27	5	24.15	2.48	1.46	___
INDEX	6	.901	0.10	5	.839	0.06	1.21	___

abbreviations: A-P = anteroposterior diameter; M-L = mediolateral diameter; Index = "shape" index calculated as M-L/A-P (ratios closer to 1 = more circular).

TABLE 12

Means and Standard Deviations of Subperiosteal Diameters for Females from the Flynt Site and the Donnaha/Forbush Creek Sites

	Flynt			Donnaha/Forbush Creek				
	n	Mean (mm)	SD	n	Mean (mm)	SD	t	P
A-P	2	26.48	2.06	7	25.62	2.50	0.43	___
M-L	2	24.15	1.83	7	24.21	2.81	0.02	___
INDEX	2	.944	.178	7	.951	.146	0.05	___

abbreviations: A-P = anteroposterior diameter; M-L = mediolateral diameter; Index = "shape" index calculated as M-L/A-P (ratios closer to 1 = more circular).

anteroposterior and mediolateral diameters. The Piedmont sample exhibits a slightly more circular index than the coastal group, but again the difference is not significant.

Comparisons between the males and females from the coastal group are presented in Table 13. The males exhibit a somewhat larger anteroposterior diameter, while the females show a slightly larger mediolateral diameter and a slightly more circular shape. These differences are not significant. It should be pointed out that the sample size for the females (n = 2) renders statistical analysis unreliable.

Table 14 shows comparisons between males and females from the Donnaha/Forbush Creek sites. While the mediolateral diameter exhibits no significant difference, the anteroposterior difference is significant at the .05 level (t-test), with males exhibiting a larger diameter. This is consistent with the archaeological evidence which suggests that the Piedmont inhabitants maintained a reliance on some aspect of hunting-gathering as well as agriculture, and practiced some form of a division of labor which would lend to males a tendency toward greater anteroposterior loading. It is also consistent with Ruff's (1989) suggestion that males in hunter-gatherer societies generally exhibit a greater anteroposterior loading adaptation than do females. If size differences between males and females accounted for the greater anteroposterior diameter, then one would expect to see a significant difference in the mediolateral diameter as well.

Comparisons between the Flynt and Donnaha/Forbush Creek groups for the combined sexes are presented in Table 15. The mediolateral diameters for the two groups differ very little. While the index derived from the two mea

TABLE 13

Means and Standard Deviations of Subperiosteal Diameters for Males and Females from the Flynt Site

	Males			Females				
	n	Mean (mm)	SD	n	Mean (mm)	SD	t	P
A-P	6	29.28	2.86	2	26.51	2.01	1.23	___
M-L	6	26.23	2.23	2	26.51	2.01	1.17	___
INDEX	6	.901	.10	2	.944	.17	.18	___

abbreviations: A-P = anteroposterior diameter; M-L = mediolateral diameter; Index = "shape" index calculated as M-L/A-P (ratios closer to 1 = more circular).

TABLE 14

Means and Standard Deviations of Subperiosteal Diameters for Males and Females from the Donnaha/Forbush Creek Sites

	Males			Females				
	n	Mean (mm)	SD	n	Mean (mm)	SD	t	P
A-P	5	28.77	1.90	7	25.62	2.50	2.36	.05
M-L	5	24.15	2.48	7	24.21	2.82	0.03	___
INDEX	5	.839	.060	7	.893	.092	1.14	___

abbreviations: A-P = anteroposterior diameter; M-L = mediolateral diameter; Index = "shape" index calculated as M-L/A-P (ratios closer to 1 = more circular).

TABLE 15

Means and Standard Deviations of Subperiosteal Diameters for Combined Sexes from the Flynt Site and the Donnaha/Forbush Creek Sites

	Flynt			Donnaha/Forbush Creek				
	n	Mean (mm)	SD	n	Mean (mm)	SD	t	P
A-P	13	28.47	2.60	12	26.94	2.71	1.44	.10
M-L	13	24.78	2.25	12	24.18	2.56	1.36	___
INDEX	13	.847	.097	12	.904	.127	1.26	___

abbreviations: A-P = anteroposterior diameter; M-L = mediolateral diameter; Index = "shape" index calculated as M-L/A-P (ratios closer to 1 = more circular).

sures indicates that the Piedmont sample shows more circularity, the difference is not significant. The combined sexes from the Flynt site exhibit a greater anteroposterior diameter than the combined sexes from the Donnaha/Forbush Creek sites. The difference is significant at the .10 level (t-test). This may indicate that the coastal inhabitants as a group exhibit an adaptation to a greater anteroposterior loading than those inhabitants from the Piedmont. In general, this contradicts the notion that labor demands should be greater in the Piedmont and may suggest that the Flynt site inhabitants experienced a more rigorous lifestyle than those of the Donnaha/Forbush Creek sites in terms of traveling to and from subsistence gathering locations. However, the subsistence pattern appears to depart from the typical hunter-gatherer patterns discussed by Ruff (1989). The absence of sexual dimorphism in the coastal group suggests that males and females participated in subsistence activities at the same level. This suggestion seems plausible given the nature of the subsistence pattern along the coast during the Late Woodland and is consistent with the observations of Meehan (1982;1977) of females participating in the coastal subsistence activities among the Anbara.

Again, it should be noted that this research is limited by the small sample size which increases probabilities of sampling error. As such, the results must be viewed as tentative.

Pathologies reported from the Donnaha (Weaver, 1984) and Forbush Creek sites suggest that the populations from both sites experienced moderate to severe nutritional and disease stress. Analysis of the Flynt site material (Bogdan and Weaver, 1989) suggests little indication of nutritional stress.

Therefore, it seems likely that nutritional stress among the inhabitants of the Donnaha/Forbush Creek sites best accounts for the decreased percentage of cortical bone area in those individuals.

However, it should be noted that Bogdan and Weaver (1989a, 1989b) and Bogdan (1989) offer strong support for the presence of a high frequency of treponemal infections among the individuals from the Flynt site. Treponemal infections manifested in the long bones can result in extensive periosteal thickening, which is often combined with cortical thickening. Additionally, diffuse nongummatous osteoperiostitis tends to leave affected long bones thick and heavy (Ortner and Putschar, 1985). Only one of the femora (SF 13) measured in this research revealed indications of syphilitic lesions. Table 3 (p. 86) shows that individual SF 13 exhibits the least percentage of cortical bone area among the males from the Flynt site. Five other individuals (SF 4, SF 6, SF 7, SF 9, and SF 12) exhibited indications of a treponemal infection in other skeletal elements. The males among this group (SF 4, SF 7, SF 9 and SF 12) exhibit percentages of cortical bone area ranging from 71.26 to 82.26. Indeed, the one male utilized in this research which exhibits no indications of treponemal infection (SF 2) has the highest percentage of cortical bone area. The female from the Flynt site which offers evidence of a treponemal infection (SF 6) does show a somewhat higher percentage of cortical bone area (70.44) than the female with no indication of a treponemal infection [(SF 3) .6628] (see Table 5, p. 89). However, the evidence of a treponemal infection present in individual SF 6 is confined to the tibia. The effects of treponemal infections on the entire skeletal system remain unclear. Weaver (personal communication) suggests that the thickening of the cortex comes about from the remodeling of pe-

riosteal reactions which result from the treponemal infection and that the infection is probably site specific. However, Weaver further suggests the probability that closer examination may reveal effects throughout the skeleton. Whether or not treponemal infections would result specifically in thickening of the cortex throughout the skeletal system remains a question which needs to be addressed. The results obtained from this research, however indicate that those individuals diagnosed as having treponemal infections exhibit lower values of percent cortical bone than those individuals which were unaffected by the disease. Such results tend to suggest that cortical bone in unaffected areas of the skeleton may tend to decrease as a result of treponemal infections elsewhere in the skeletal system. However, modern treponematosis is a highly variable condition, with seemingly opposite effects from one individual to the next (Weaver personal communication). Therefore, it is unreasonable, at this level of research to state emphatically that treponemal infections result in a thinning of the cortex in uneffected areas of the skeletal system. Further research in this area should help to shed light on the question of treponemal effects throughout the skeletal system.

CHAPTER IX

SUMMARY

So complex are the interactions among food compounds, and so varied are the behavior and the chemistry of individuals, that dietary intervention has proved to be one of the most complicated of all medical treatments, subject to unexpected difficulties and disappointing results. Thomas J. Moore (1989)

Such are the problems facing medical researchers today in their battle against coronary heart disease. These problems surface in the face of state of the art technology and sophisticated laboratory techniques designed to gain an understanding of the interaction between diet and bodily functions which lead to certain levels of health in modern populations. These problems also occur in spite of the fact that researchers have access to information regarding the behavior patterns and foods ingested by their subjects. Additionally, information is available on a continuum of traits ranging from stature, weight, body fluids and vital signs all the way to geneological histories of disease. In short, much knowledge regarding the specific functions of dietary nutrients, as well as their effects upon the human body has yet to be obtained.

The physical anthropologist is presented with few of the nutritional indicators which are available for living populations. The material the anthropologist is working with (skeletal samples from an archaeological context) often results in samples of inadequate size or preservation. Moreover, while the

anthropologist is restricted to the study of skeletal remains, the end product, i.e. dry bone reflects not only diet but also the digestive and endocrine systems (Raisz and Kream, 1983; Cook et al., 1988), disease (Ortner and Putschar, 1985; Bogdan and Weaver, 1989; Garruto et al., 1989; Reichs, 1989), trauma and mechanical stresses (Ruff, 1987a; Fresia and Ruff, 1978; Ericksen, 1976) acting on the skeletal system prior to death as well as diagenetic influences after burial.

During the last decade, physical anthropologists (e.g. Huss-Ashmore et al., 1982; Martin et al., 1985; Larsen, 1987) have begun to recognize the need for research which deals with multiple stress indicators involved in the manifestations of maladies observed in human remains recovered from archaeological contexts rather than attempt to diagnose a specific nutritional deficiency such as rickets or scurvy. Towards this end, physical anthropologists need to concern themselves more systematically with basic biological processes. Specifically, a working knowledge of skeletal processes is vital to accurate and reliable research.

The results of this research appear to support the hypothesis and portray the inhabitants of the North Carolina coast during the Late Woodland as a healthy, well adjusted population with regard to subsistence adaptations. Additionally, the measures of femoral diameters suggest that the coastal adaptation allowed for an evenly distributed division of labor by sex.

However, Bogdan and Weaver (1989a; 1989b), and Bogdan (1989) offer strong support for a high incidence of treponemal infections within the coastal population utilized for this research. Treponemal infections manifested in the long bones can result in extensive periosteal thickening, which is often combined with cortical thickening. Additionally, diffuse nongumma-

tous osteoperiostitis tends to leave affected long bones thick and heavy (Ortner and Putschar, 1985). Only one of the femora measured in this research revealed indications of syphilitic lesions. However, five other individuals exhibited indications of a treponemal infection in other skeletal elements. The effects of treponemal infections on the entire skeletal system remain unclear. Weaver (personal communication) suggests that the thickening of cortex comes about from the remodeling of periosteal reactions which result from the treponemal infection and that the infection is probably site specific. However, Weaver further suggests the probability that closer examination may reveal effects throughout the skeleton.

Whether or not treponemal infections would result specifically in thickening of the cortex throughout the skeleton remains a question which needs to be addressed. This research suggests that cortical thickening resulting from treponemal infections is most likely confined to the specific location of the disease and raises the possibility that a specific treponemal infection may result in a thinning of the cortex throughout the skeletal system. However, modern treponematosis is a highly variable condition which appears to manifest itself differently from individual to individual (Weaver, personal communication). Therefore, suggestions regarding the treponemal infections present in the coastal sample must remain tentative until further research clarifies the interaction between such infection and the human skeletal system.

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VITA

David C. Jones was born in Norfolk, Virginia on December 23, 1953. His family moved to Washington, North Carolina in 1960, where he attended public schools until 1969. At that point, he was sent to Randolph Macon Academy, by order of the district court. He graduated from Randolph Macon Academy in June of 1972.

He then became self-employed with a friend in the seafood business in Swansboro, North Carolina until 1981, at which time he enrolled in school at the University of North Carolina at Wilmington. He was graduated in August of 1984 with a Bachelor of Arts in Sociology and Anthropology.

Following one year in a concentrated search for a wife, he enrolled in graduate studies at the University of Tennessee at Knoxville. The search paid off and he was married to Emily Freeman in September of 1987. After graduation he anticipates returning to the seafood business in North Carolina.

He has no children nor any known communicable diseases.