ASYMMETRY AND ACTIVITY-RELATED CHANGE IN SELECTED BONES OF THE HUMAN MALE SKELETON.

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For Derek

". . . when you can measure what
you are speaking about and express it in
numbers, you know something about it;
but when you cannot express it in numbers, your
knowledge is of a meagre and unsatisfactory
kind; it may be the beginning of knowledge, but
you have scarcely in your thoughts advanced
to the state of science, whatever the matter may be."
Lord Kelvin

ABSTRACT

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Thesis submitted by Ann Jane Stirland of the Institute of Archaeology, University College London, for the degree of Doctor of Philosophy, 1992.

Statistical analyses of measurements were used to evaluate congenital asymmetry and activity-related change in 100 pairs of humeri and 112 pairs of femora. Bone pairs in samples from the *Mary Rose* and an earlier medieval site in Norwich were subdivided into age categories and their archaeological groups for analysis. Internal bone dimensions were determined from radiographs and compared with those of a modern group of divers. Muscle insertions were ranked and femoral morphological traits were recorded. Differences were tested at the $p < 0.05$ level of confidence. Congenital asymmetry was accepted from earlier work for maximum length of the humerus. Asymmetries decreased with age in the humerus and to a lesser extent in the femur. The humerus was shown to have significant right-sided dominance while the femur was more symmetric. Accepted methods of measuring femoral torsion were demonstrated to be inadequate. Femoral morphological traits were shown to be affected by environment. Significant results obtained from new measurements may be attributable to patterns of activity in the *Mary Rose* sample. These individuals were significantly taller and larger than those of the Norwich sample. Selection, diet and activity are discussed as possible explanations for these increases. Statistical comparison of compatible groups may reveal patterns of activity, if the occupations in the groups are known.

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The work was performed solely by the author. The results of other work are acknowledged in the text and a list of references is given at the end of the thesis.

CHAPTER 1 MATERIALS:

SITES AND SAMPLES.

1.1 INTRODUCTION.

The object of this research is to study the possible effects of patterns of activity or occupation on the male skeleton, and to attempt to discriminate this environmentally determined variation from congentially established asymmetry. Two related projects have already been completed. In the first, the frequency of os acromiale was evaluated in relation to occupation (Stirland, 1984). It was argued that, in particular samples from the *Mary Rose*, the non-fusion of the final element of the acromion process of the scapula was related to the persistent and long term use of the very heavy long bows found on the ship. In the second, the problems involved in the diagnosis of occupationally related palaeopathology were addressed (Stirland, 1991).

The materials used in this research consist of samples of human remains from two archaeological sites, plus a sample of *in vivo* bones. In this chapter both the archaeological sites and the skeletal samples will be described.

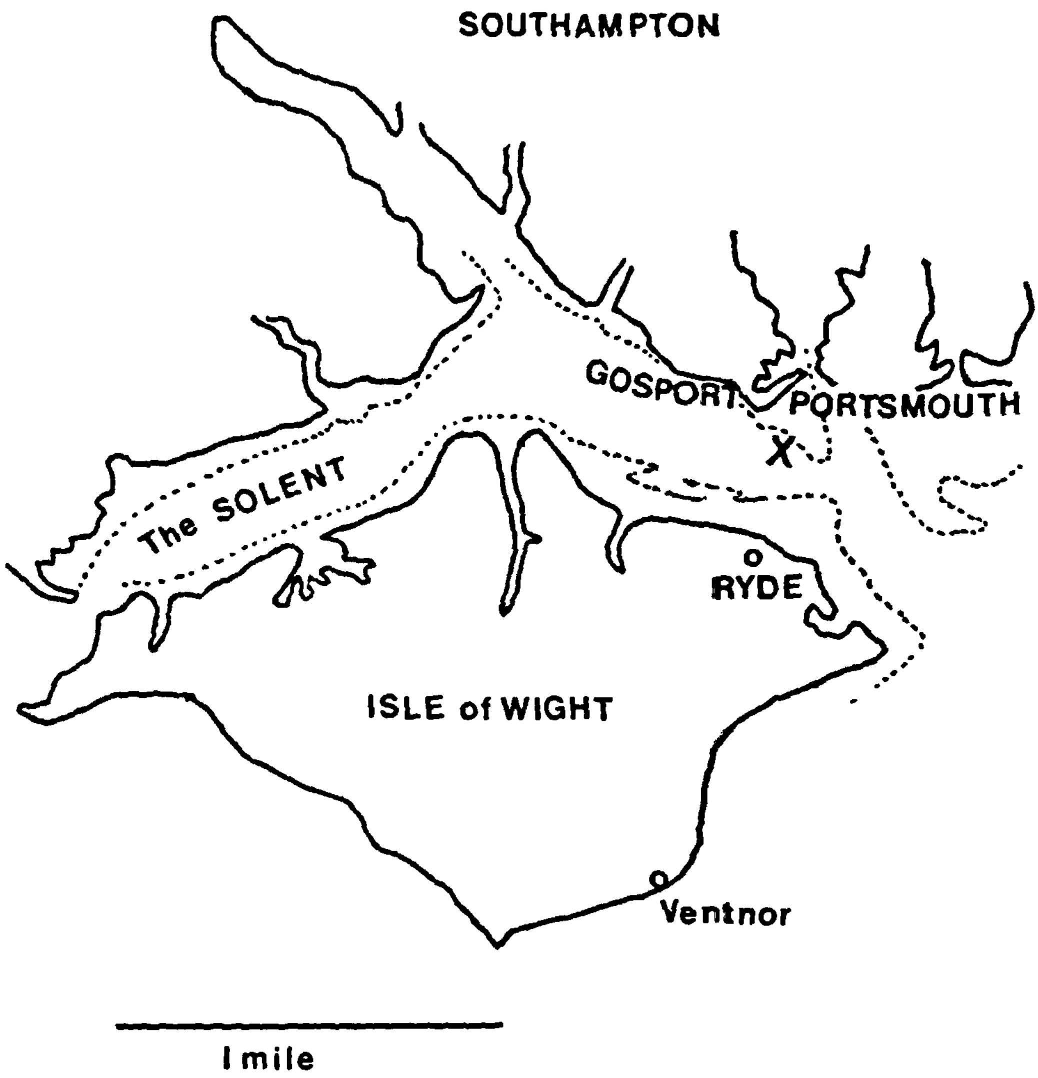
1.2 ARCHAEOLOGICAL SITE 1: THE *MARY ROSE*.

On the morning of 19 July, AD 1545 King Henry VIII's flagship, the *Mary Rose*, came out of Portsmouth harbour with the rest of the English fleet, to engage with the French who were moored off the Isle of Wight, (Rule, 1982). On attempting to raise sail, the ship heeled over and sank, coming to rest heavily on her starboard side, just outside the harbour entrance "partly (owing) to defects in her construction, partly to neglect of precautions on the part of her crew " (Hannay, 1898). Map 1 illustrates the Solent and the *Mary Rose* wreck site. Of the 415 crew, all save some three dozen were drowned, trapped by the anti-boarding netting which covered the exposed decks. The wreck was rapidly abraded and silted up by the four tides a day which occur in the Solent; she was finally sealed by a hard, shelly sea-bed. Figure 1.1 illustrates the silted and sealed wreck of the *Mary Rose*. This sealing had two effects:

1. The wreck remained substantially hidden for most of the next 437 years;
2. An anaerobic environment was formed in which the silts allowed excellent preservation of many organic remains (Stirland, 1986).

The story of the discovery, excavation and raising of the *Mary Rose* in 1982 is well known and will not be discussed further (see Rule, 1982). Among the many remains, however, was some excellently preserved human skeletal material. Such human remains from ancient wrecks are rare and, in this case, reflect the rapidity and efficiency of the sinking and silting up of the wreck. In archaeological and historical terms they are unique, since they represent an absolutely dated, late medieval Tudor group of men from a fighting ship. Although there are only three known individuals from the ship, (the Vice Admiral, the Captain and the Master - all of whom perished), the activities in which the men were engaged are listed in the Anthony Roll, completed in AD 1546 (Rule, *ibid.*).

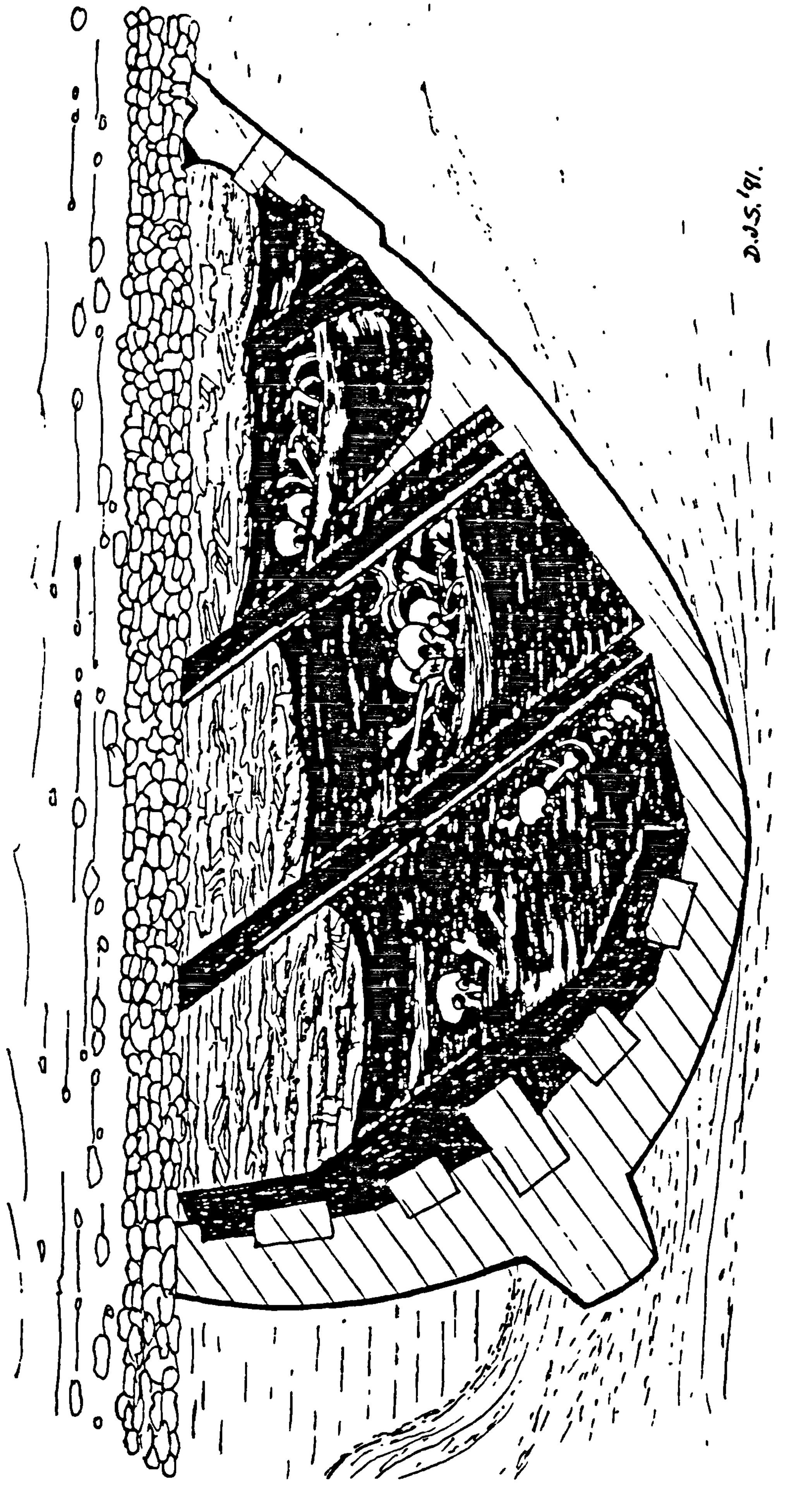
Map 1: The Solent and the *Mary Rose* wreck site.



Location of the wreck of the *Mary Rose*.

X marks the site of the wreck.

Figure 1.1: The silted and sealed wreck of the *Mary Rose*.


D.J.S. '91.

1.3 SKELETAL SAMPLE 1: THE *MARY ROSE*

From 1982 to 1985 the author was engaged, by the Mary Rose Trust, in the analysis of the human skeletal remains from the ship. (A report on the preliminary findings was submitted to the Trust in March 1985, but has not as yet been published). During the course of the analysis it became clear that, when compared with other archaeological samples, this skeletal material was somewhat exotic. The bones were large, heavy and strong with very well marked fibrous insertions and relatively high frequencies of traumatically induced anomalies such as osteochondritis dissecans (Stirland, in preparation). One correlation between boney change and pattern of activity has already been suggested (Stirland, 1984).

The condition of the skeletal material from the *Mary Rose* is excellent and because the remains are unique it was decided to expand the work into a full-time research project. However, it was felt from the beginning of the work that attempts to record changes in bones which may be related to activity should take account of the underlying asymmetry in such bones. Consequently, the present research has been based primarily on the evaluation of asymmetry in two pairs of bones.

The material from the *Mary Rose* was totally commingled. Some re-sorting was undertaken at the time of the original analysis, and 92 fairly complete skeletons were derived from a minimum number of 179 individuals, based on a skull and mandible count. It is accepted that, in such a commingled group, the 92 'individuals' may be an artefact. At the time of the original study and report it was considered politically expedient to attempt to reconstruct individuals from the material excavated from the sectors of the ship (Stirland, in preparation). The re-sorting was undertaken on the basis of gross anatomy and by matching paired bones from each archaeological sector of the ship, thus 'constructing' a skeleton from pairs of bones and their accompanying joints. (Vertebral columns were assembled upwards from the first sacral vertebra. A skull was included only if the whole column including the first cervical vertebra was present, and could be matched to it. Sacra were matched to innominates at the sacro-iliac joints). One could never be absolutely sure, however, that all the bones in each skeleton were correctly matched; this was particularly true for the upper limbs and pectoral girdle and for the hands and feet. Therefore, it was decided to compare the asymmetry of two paired bones, the humerus and femur, for the following reasons:

1. They could be paired in the sample with reasonable confidence;
2. During physical activity they are often heavily loaded, and they exhibit sites of major muscle insertion;
3. Anatomically, the two bones have similarities:
a) They are single long bones comprising the arm and the thigh, compared to dual bones which comprise the forearm and leg. Thus, there is no complication of 'shared' stresses as would be the case if comparisons were being made, for example, between the ulna and tibia or the radius and fibula.
b) Both the humerus and the femur articulate with one girdle of the body, i.e., the pectoral for the former and the pelvic for the latter.
c) Both bones are involved in the classic ball and socket synovial joints of the body; the head of the humerus articulates with the glenoid of the scapula and the head of the femur with the acetabulum of the innominate. Much movement is involved in these axial

joints, whereas both with the elbow and the knee joints essentially only flexion and extension are involved.

d) In evolutionary terms, the humerus and the femur are essentially identical bones which have phylogenetically evolved for different purposes - the upper limb for sophisticated tasks and the lower limb for bipedal locomotion. For all the above reasons, the humerus and femur are ideal bones on which to base a study of skeletal asymmetry.

It should be noted that the form of this research has been dictated by the nature of the archaeological group from the *Mary Rose*. Initially, it was intended to use bones that appeared to come from the same individual. Later it became apparent that in such a commingled group it was impossible to associate a specific pair of humeri to a particular pair of femora from the same individual. Therefore, the pairs of humeri have been treated as a separate group from the pairs of femora.

Sexing of the material was done by the author as part of the original analysis; all bones used in this study were those of males. Methods of both sexing and ageing are described in chapter 3.

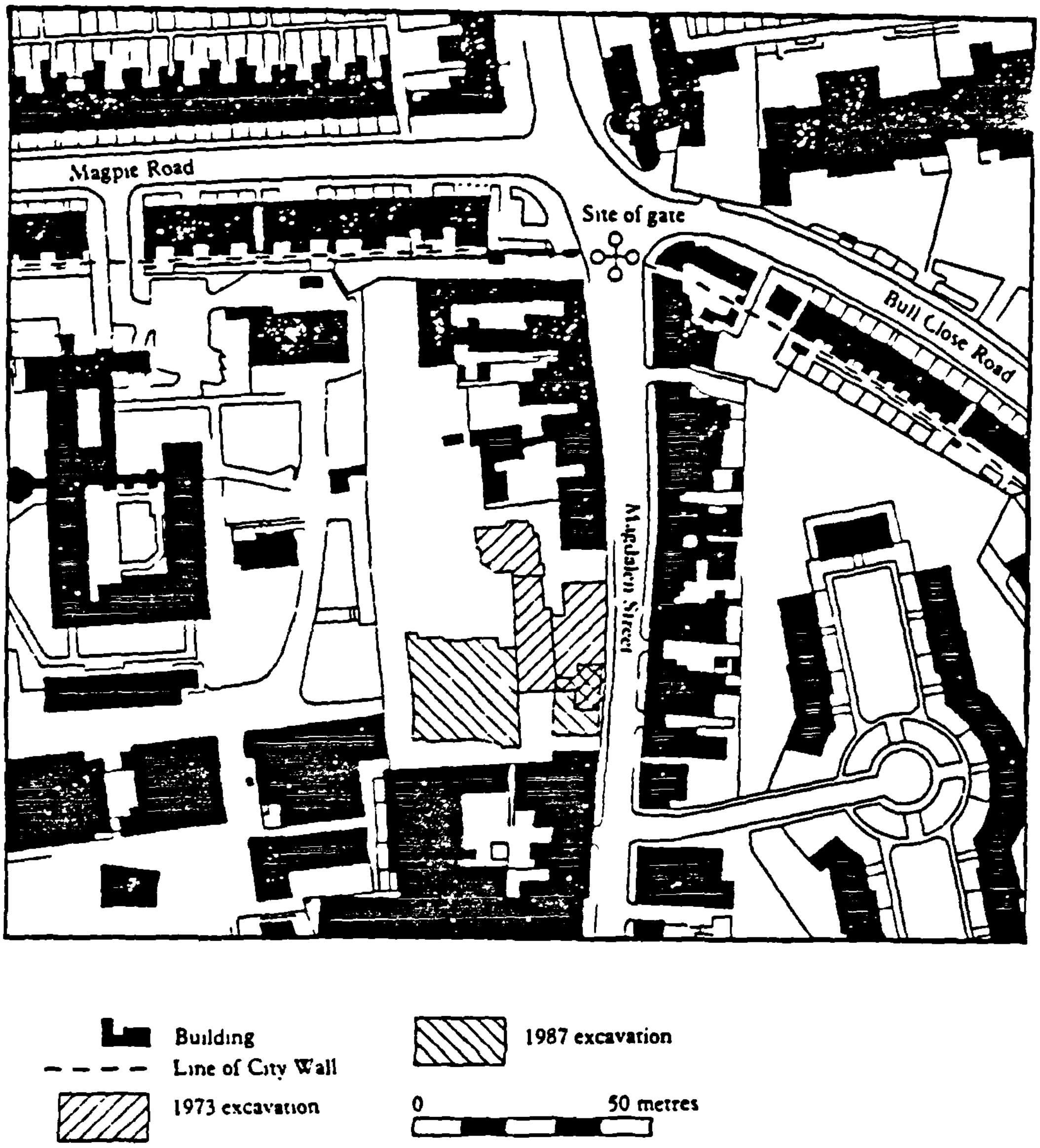
1.4 ARCHAEOLOGICAL SITE 2: NORWICH.

The problem in finding a skeletal group which can be compared with the *Mary Rose* group results from the archaeologically late date of the latter. Ideally, a large late medieval group from the southern part of England was required.

St. Margaret *in combusto ubi sepeliunter suspensi* was a medieval church situated at the northern end of Magdalen Street, Norwich. Its name indicates both 'in the burnt area' and a church used for the burial of those who have been hanged. It served, therefore, as a poor parish church and as a burial ground for gallows victims. The medieval city gallows was situated outside the walls and beyond the Magdalen Gates (Ayers, 1987). Although the church was demolished some time ago, the cemetery was thought to have survived on the site. The last recorded burial occurred in AD 1468 and the church itself was first recorded in AD 1254. When Victorian shops were built along the street, some burials were disturbed (J. Bown, 1991); the construction of deep cellars had destroyed part of the cemetery and the foundations of the church. In 1973 it was proposed to develop the site, which was by then a piece of waste ground. Consequently, a rescue excavation was undertaken at the site of the street frontage and shops. Map 2 illustrates Magdalen Street and the area of the excavations. Charnel pits were encountered, where the disturbed burials from the Victorian building had been re-interred, together with a small number of inhumations. The development was abandoned, however, and not contemplated again until 1987. This time the entire site, rather than just the street frontage, was to be developed and Norfolk Archaeological Unit were employed by the developers to excavate the site ahead of the development (see map 2). Given the previous discovery of so few inhumations in 1973, they anticipated finding largely charnel material in this later excavation. When the trial trenches were opened, however, sufficient individual inhumations were encountered to indicate that a cemetery was present.

The cemetery of St. Margaret *in combusto* appears to be unique in form. About 70% of the graveyard was excavated, mainly to the west of the church. There were at least 20 group burials, where several individuals had been interred together, as illustrated in figure 1.2.1. Figure 1.2.2 illustrates one of these groups, where individuals had been buried prone rather than supine, some with their hands behind their backs. In other groups, some individuals were placed in a different orientation to the others, reversed from the normal Christian pattern and buried facing east-west, or even north-south. Other examples revealed individuals who appeared to have been thrown into a common grave, while some had been most carefully buried in a group pit, presumably all at the same time (see figure 1.2.2). Unusually, some bodies were fully clothed when buried (Ayers, *op. cit.*). A total of 436 inhumations were excavated from the site and at least an equal number were removed as disassociated material. The individuals represented by these burials are not a random sample; they are not necessarily representative of medieval England or of medieval Norwich. It is not possible to say which of the burials are of hanged criminals and which are of the parish; some of the carefully buried groups may represent epidemic deaths from, for example, plague (Ayers, *op. cit.*).

Map 2: Magdalen Street showing the area of the church and the 1973 and 1987 excavations.



Location of the 1987 Magdalen Street excavation. The gallows was to the north of the City Gate in Magdalen Road.

Figure 1.2.1: Group burial from Magdalen Street.

Figure 1.2.2: Prone burials from Magdalen Street with hands behind their backs.

1.5 SKELETAL SAMPLE 2: ST. MARGARET *IN COMBUSTO.*

The 436 inhumations from this site yielded a large number of adult males. As with the sample from the *Mary Rose*, the author undertook both the sexing and ageing of the Norwich material, (the methods used are described in chapter 3). 55.1% of the total number of skeletons that could be sexed were male. There is some mixing of burials on this site, largely due to the existence of the groups. However, the inhumations were received as individuals and they have been sexed and aged as such. For the reasons given in the case of the *Mary Rose* material, pairs of humeri and femora from this group have also been studied separately. Unlike the *Mary Rose*, however, the pairs of humeri and femora in this case are largely, although not exclusively, from single individuals.

Like other archaeological samples, neither of the ones used for this research are random; they represent the remains that have survived. Further, the *Mary Rose* sample was selected at source, when the ship was crewed and again when the ship was excavated. (Of approximately 395 men who drowned only about 179 were excavated). In the case of the Norwich sample, this was also selected at source and probably consisted largely of 'criminals', or at least of men who had been executed. It, too, was archaeologically selected, since the excavation sample was incomplete. It would, therefore, be inappropriate to generalise any findings from these two samples to offer comments on the general medieval population.

1.6 SKELETAL SAMPLE 3: THE DIVERS.

In order to establish a control group for some of the measurements at least, it was decided to try and obtain radiological data from a modern group. It is uncommon these days to find a series of radiographs from a specific group of individuals. In the past, various studies have been undertaken which involved whole body radiographs of groups of individuals from birth to adulthood (Cox, 1989). The dangers of such persistent and unecessary exposure to X-rays is now understood and such studies are no longer undertaken. Serial radiographs are therefore uncommon.

Initially, a series of films taken of the 1960 British Team at the Rome Olympics was provided by Professor Tanner. They proved to be unusable, however, for the following reasons:

1. The quality of the films was poor and the deterioration was such that it was not possible to take either useful or accurate measurements.
2. Only the humerus and femur on the left side had been X-rayed.

Other series were sought and, eventually, an excellent group was obtained from the Radiography Department of the Royal Naval Hospital at Haslar.

The Royal Navy radiographs all their divers every year or so throughout their diving life. The men are volunteers and are selected to be physically very fit before being trained as divers (Jarvis, 1989). Bilateral radiographs are taken of the shoulder and upper humerus, the hip and upper thigh and the knees and lower thigh. This is undertaken in order to check for the development of dysbaric bone necrosis, a pathological change associated with decompression which occurs in the joints of some divers. The author was permitted to examine and measure 50 of these radiographs of normal individuals of <30 years of age.

The material studied for this research has been examined from two archaeological groups and by age-matched cohorts. The size of the final samples of matched bones was such that only two age groups have been used - Young Adult males and Mature Adult males. The criteria for inclusion in the two groups and the size of the entire sample will be discussed in chapter 3. This thesis will attempt to answer the following questions:

1. To what extent is asymmetry exhibited by the humerus and the femur in the male skeleton?
2. What are the similarities and differences in asymmetry between the archaeological groups?
3. Are the asymmetries and differences present in the samples affected by size or by activity in either bone?

CHAPTER 2 SKELETAL ASYMMETRY AND ACTIVITY: LITERATURE REVIEW.

2.1 INTRODUCTION.

Human bilateral asymmetry may be defined as a variation in size between the two halves of the body. While bilateral asymmetry in the body as a whole has long been recognised, the first work on skeletal asymmetry was undertaken by the anatomist Arnold in 1844 (Schaeffer, 1928). Arnold established the dominance in length of both the right humerus and forearm and of the left femur. Thus, the idea of a "crossed symmetry" or the dominance of the right arm and of the left leg was established. A later 19th century study (Garson, 1879) found that the left lower limb is frequently longer than the right. This study also demonstrated that the difference between the limbs is on average greater when the left is the longer.

Clearly, when studying paired bones to evaluate activity-related change which is non-pathological in character, both the degree and the kind of asymmetry present should be considered. Attempts have been made to establish which, if any, of the humeral and femoral asymmetries are congenital in origin; (a congenital condition must, by definition, be present at birth). Only one asymmetry in either pair of bones has been shown to be congenitally present. This is the maximum length of the humerus (Schultz, 1937). It is the only asymmetry which will be considered as congenital in origin in this thesis.

It is clear from the simplest of measurements, such as the maximum lengths of a pair of bones, that there usually are differences between left and right. However, differences due to patterns of use, if they are exhibited in the skeleton, are superimposed on this fundamental asymmetry. A brief review of previous publications in these areas is given in the following sections.

2.2 ASYMMETRY.

The most marked and commonly reported skeletal asymmetry in humans is handedness, or the dominance of the right upper limb over the left. Recent research (Falk, 1987), has related handedness to cerebral lateralisation; the "dominance" (*sic*) of the left hemisphere has favoured control of the right upper limb by motor areas in the left frontal lobe of the brain. This may explain why at least 90% of humans are right handed. Woo (1930) endeavoured to establish whether asymmetry in areas of the brain was matched by similar asymmetries in the skull. Using a series of measurements he demonstrated that the human skull is "markedly asymmetrical" (p339) and that the right side has dominance over the left. In contrast, other research (Plato *et al.*, 1980) has demonstrated an inherent tendency for the right second metacarpal to be larger than the left, regardless of dominance. Attempts have been made to evaluate handedness in dry bone. For example, while examining the American dead from the Korean War, Stewart (1979) noticed that the right scapula was often distinguished from the left by a bevelling of the dorsal margin of the glenoid fossa; he saw no cases where the bevelling was more noticeable on the left. There was no mention of individual handedness in the military records. When Stewart examined 128 male skeletons from the Terry Collection (1976a, reported in Stewart, 1979) he found the same differential bevelling of the fossae. This later work also demonstrated "a tendency" (*sic*) for the plane of the right fossa as a whole to be more dorsally inclined than the left, and for more torsion of the right humerus. Stewart found two other "extreme" cases in the Terry Collection, in which the changes were on the left rather than the right side.

In these, the most marked differences were in the humeral lengths, although the fossae on the left were more bevelled and more dorsally inclined than those on the right. Stewart reported no intra or inter-observer measurement errors in his studies and no statistical analysis of any kind was reported.

Schulter-Ellis (1980) examined the accuracy of Stewart's methods for determining handedness. Her very small sample consisted of only five male and five female cadavers of known handedness. The data collected from them, together with the presence or absence of Stewart's bevelled glenoid, were compared with the known handedness. This study indicated that bevelling, degree of dorsal inclination of the glenoid fossa, greater total length of the bones and maximum humeral epicondylar width were all positively correlated with the dominant side. Schulter-Ellis also argued that there was a positive correlation between the presence of the bevelling and physical activity and that, in at least one of her specimens, the asymmetry might have been produced by activity. Two points should be made regarding this work: firstly, the sample size was far too small to permit any statistical analysis and, secondly, all the individuals in the sample were in excess of 52 years of age.

Schultz (1937) compared skeletal variability and asymmetry between various human groups ("civilized and uncivilized races of man", p281) and other primates, especially gorilla, chimpanzee, orang-utan and rhesus monkey. Long bone lengths and some indices were compared between all the groups, including humeral and femoral maximum lengths. Among other results, the arithmetic means of the variation coefficients of the humeral and femoral lengths were compared. These comparisons demonstrated far more variation in man than in the other primates studied (p305). Evaluation of asymmetry in human humeri further demonstrated that, even in the fetus, asymmetry in the upper limb favours the right side (p308). Asymmetry in the lower limb was found to be less marked than in the upper.

Jolicoeur (1963) applied multivariate statistical methods to Schultz's human data and also to a group of adult *Martes americana* (marten) skeletons which he had measured. The aim of the study was to attempt to evaluate asymmetry in the humerus, radius, (in man only), the femur and the tibia between the two species; only long bone lengths were used. This later analysis agreed with Schultz's results in showing a marked dominance of the right upper limb and a less pronounced dominance of the left femur in man. It was argued that the marked asymmetry of the upper limb in man is related to the development of functions other than locomotion.

Studies of asymmetry in species other than man include those by McNeil *et al.*, (1971) and Falk *et al.*, (1988). In the former, asymmetry in parakeets was found to be related to handedness. The paper demonstrated a close but not a causal relationship, and discussed views of asymmetry as either an inherited or an environmental characteristic. In contrast, Falk *et al.*, (1988), found skeletal asymmetry in the forelimb of *Macaca mulatta*, (rhesus monkey), to be similar to that in humans, showing a predominance for the right side. The results in this case were interpreted as due to an hypertrophy of certain muscles that control the movements of the hand at the wrist; inherent asymmetry was not discussed.

Attempts have been made to establish whether or not inherent asymmetry in man is genetic in origin. Pande and Singh (1971) dissected and weighed specific bones and muscles from the upper limbs of ten fetuses and calculated the total weights for each side; the heavier limb was assumed to be the dominant one. They discovered that the total muscle and bone weight was greater on the right side in nine of the ten fetuses and concluded that the right-sided dominance of the upper limb in man is, therefore, genetic in origin. In an earlier study on asymmetry in muscle weight in the lower limbs Chhibber and Singh (1970) dissected and weighed the muscles and bones from ten adult cadavers. Using total limb weight as a criterion of greater use they found that in seven of the ten the left limb was dominant. No correlation between dominance in the upper and lower limbs was observed and no reasons were proposed as to the cause.

A paper by Lowrance and Latimer (1957) examined the weights and linear measurements of 105 Asian skeletons. The bones from both sides were measured and the averages of the lengths were calculated. Analysis showed that the three major long bones of the upper girdle were often longer (and heavier) on the right side, while those of the lower girdle were more symmetrical, but with a tendency for the left side to be longer. In a later paper using the same material Latimer and Lowrance (1965) reinforced their earlier findings. They found that all the methods they used for studying asymmetry seemed to indicate that, generally speaking, the bones of the upper limb were longer and heavier on the right side while those of the lower limb were more uniform; the femur tended to be longer and heavier on the left.

Evaluation of a large sample of humeri from a documented ossuary (Pfeiffer, 1980) demonstrated that there is an increase with age both in lateral, non-linear dimensions and of the dominant side. Six of the eight measurements chosen showed significant differences with age on the right side, while only one showed a statistically significant difference on the left side. The important point was made that disregarding the ages at death of individuals in a skeletal sample will significantly bias the results of any analysis.

This short review has attempted to demonstrate that there has been a variety of explanations given for skeletal asymmetry, in man and other species. In some research allowance was made for inherent asymmetry, and statistics of various kinds were applied to the raw data. In other studies very small samples were used, no allowances were made for inherent asymmetry and in some cases no statistical analysis was undertaken. Do the same limitations apply to research on asymmetry and activity?

2.3 ASYMMETRY AND ACTIVITY.

Recently, it has become "fashionable" to attribute some asymmetric skeletal changes to occupation or to patterns of activity. While some authors have been cautious in attributing such an environmental explanation, (see, for example, Watson, 1973, Ruff and Jones, 1981 and Schell *et al.*, 1985), others have been more ready to make positive associations (one of the more startling is that by Angel *et al.*, 1987).

Much research has been published on the relationship between the development of degenerative joint disease and patterns of work in living groups (see, for example Lawrence, 1955 and 1977; Lockshin *et al.*, 1969; Anderson, 1971 and 1974; Hadler *et al.*, 1978; Hadler, 1980; Sairanen *et al.*, 1981). A well-known study of activity-related skeletal change in an archaeological sample also used the presence and pattern of joint change to reconstruct past behaviour (Merbs, 1983).

Habitual activity may induce changes in the musculo-skeletal system and some clinical work supports this view. For example, repetitive strain injury (RSI) is becoming increasingly well documented and recognised clinically (Bird, 1990). The first case of (keyboard) RSI to reach the courts was reported recently ("The Guardian", 1991), thus demonstrating that this condition is now an accepted basis for legal claims.

Prives (1960) examined the influences of occupation and of sport on the structure of the human skeleton. Various clinical studies of the changes induced in areas of the musculo-skeletal system by the systematic practice of particular sports have also been made (for example, Mann and Littke, 1989). Studies on activity-induced change in archaeological skeletal material are variable in the degree to which they relate what they observe to clinical practice. For example, Ubelaker (1979), found only one clinical reference which indicated similar changes to those which he saw in metatarsals and phalanges and which he attributed to habitual kneeling. This paper presents a careful argument for marked alterations to the bones, with clear examples, and the author discusses the problems involved in his diagnosis. In contrast, Molleson (1989) took Ubelaker's diagnosis as proven, in spite of his reservations. She used the 'evidence' from this earlier work as a basis for a positive diagnosis in a Mesolithic group. The sample in this research was "very incomplete and poorly preserved" requiring most of the combination of joint changes to be "pieced together from the examination of isolated fragments" (p357). Similar changes in the foot to those seen by Ubelaker were used as 'proof' of persistent seed grinding while in a kneeling position. Development of muscle insertions, particularly those of deltoid and biceps were used as further 'proof' of the action of grinding, together with other dental and skeletal changes. Molleson made no reference to clinical parallels, a common fault in much activity-related research. The other common fallacy of accepting published findings as 'proven facts' is exhibited by these results. Neither differences of age nor of symmetry were included in either of these papers.

Acceptance of particular changes in the skeleton as diagnostic of specific activities is a recurring theme in the literature. An early example related the development of the deltoid tuberosity of the humerus to the persistent operation of a sling shot in the Roman army (Fawcett, 1935). A recent example has more serious implications, since it discussed the supposed activities of extinct groups as if these activities were known (Bridges, 1989). In this paper the 'known' activites were based on dubious historical and ethnological data. The unreliability of this data was amplified by the use of further data for the essential background information from sites other than those actually studied : "Given the lack of subsistence information from these floodplain sites, historical and archaeological analogy and data from the nearby uplands *must be used to reconstruct* Mississippian systems in this region", (p386, my italics). Very general statements, without references, were made about "worldwide' health and morbidity with the introduction of agriculture. The prevalence of osteoarthritis was directly related to activity and neither age nor asymmetry were considered in the analysis of the samples.

Dutour (1986), attempted to relate enthesopathies, (the formation of enthesophytes at the sites of muscle insertions (Niepel and Sit'aj, 1979) to patterns of activity in two Neolithic Saharan groups. The total sample was 41 individuals, of which 21 could not be assigned a sex, and no allowance was made for age-related changes. The problem of extracting evidence from small samples is a recurring one. Borgonini Tarli and Repetto (1986) used a sample which consisted of only two adult females and five adult males from a Mesolithic site in Sicily and compared them in various ways with other, often very large, samples. For example, the stature of this group was compared with other European groups ranging from the Upper Paleolithic to the present, and limb proportions were compared from the Upper Paleolithic to the Early Medieval periods. No age groups were indicated and both sexes were pooled. There was no evaluation of the underlying asymmetry and no statistical tests were applied. Formicola (1986) compared two samples of adult males , consisting of five and eight individuals, respectively. In this case, only two skeletons were found to be in the correct anatomical relationships archaeologically, the others had to be reconstructed. A very high degree of asymmetry was observed and the author speculated as to whether his samples were correctly matched; no ages were given.

Tainter (1980) discussed the relationship between skeletal change and social ranking. Pathological processes were not clearly understood in this analysis, which grouped whole areas of the skeleton together, and no numbers of individuals were given. Similarly, a paper by Constandse-Westermann and Newell (1989) tried to relate limb lateralisation to social stratification in the European Mesolithic citing the papers discussed above, among others. Definitive statements were made in this paper about direct relationships between joint degeneration and activity stress on the one hand, and between lateralisation and differential use of each limb on the other. The sample sizes used were very variable and in some cases very small. The stratum numbers in the individual cemeteries, on which the arguments were based, were also small. No age ranges were given for the samples and no attempt was made to distinguish handedness or inherent asymmetry from activity-related change. The results were used to indicate the equal status of women in these Mesolithic societies, thus venturing into the whimsical. There was great insistence on activity-related arthritic change *per se*.

Work has been performed in North America on various slave and free Black populations. Kelley and Angel (1987) compared three archaeological Black populations, comprising a total of 92 adults spanning the 18th and 19th centuries; a 20th century forensic Black sample was also included for comparison. This paper sought to demonstrate the "life stresses" involved in slavery, particularly by the evaluation of various "nutritional stress" (*sic*) indicators. The evidence for occupation and work stress in a population from one of the sites, Catoctin Furnace, was discussed. Particular attention was given to the development of areas of muscle insertion, especially on the humerus and ulna. Although all the illustrations used were from older adults (a male of 53 and a female of 50 years) the authors stated that similar development occurred in young adult females and adolescents. They inferred from this that the individuals concerned were involved in heavy labour at a relatively young age. Pathological states, however, may also be resposible for such entheseal development (Rogers and Waldron, 1989). The authors continued by associating patterns of arthritic change with specific occupations, based on some rather startling assumptions.

For example, they stated that:

"Crafts or the heavy work of digging the ore as well as housework were the occupations of female slaves as their arthritis patterns indicate" (p208), and

"Arthritis at the elbow suggests heavy use of triceps, as in pounding pig iron or digging out ore from the banks", (*ibid.*).

(It is clear from work published in the same year as the above paper that the attribution of arthritic changes must be securely based in modern clinical practice for such comparisons to be made (Rogers *et al.*, 1987). Further, work with skeletal material when occupations were known failed to show a positive correlation between a specific occupation and the osteoarthritic lesions present (Waldron, 1991). It is obvious, therefore, that the direct correlation of osteoarthritic lesions in dry bone and specific work loads is very difficult to make, even where the work involved is documented, rather than speculative).

In parallel work (Angel *et al.*, 1987), the Black community studied was a free one, dating to the 19th century and consisting of 75 adults. In the section on occupation, the authors compared this site with the previous one discussed above (p222). Again, they discussed development of areas of muscle insertion in terms of specific activities, deducing in one case that a female was a laundress, from the development of the area of insertion of deltoid. Such attribution of specific activity to the development of one muscle is a common failing. Few authors discuss the fact that muscles do not act in isolation but operate together in a range of movements; this is particularly true of deltoid. Angel *et al.* attributed occupation to their "laundress" because Abolition Society Records list that particular occupation for half of the free Black females in 1838. This is not 'proof' based on 'fact'. It is speculation based on boney changes which might have a variety of alternative explanations. Asymmetry was not considered in this paper.

An urban slave population from New Orleans was studied by Owsley *et al.* (1987). The cemetery was in use from AD 1720 until about AD 1810 and consisted of a total sample of 32 individuals (3 of whom had no bones preserved) including 14 males and 12 females. All bone changes assumed to be related to occupational activity were regarded as pathological; they included "ossification of connective tissues" and arthritic change. The latter has been discussed above; the former was mis-diagnosed by the authors as myositis ossificans, a neoplastic change in soft tissue which often accompanies trauma. From their own description of the lesions (p191), the boney proliferations present in this group were probably enthesophytes, which have a varied aetiology (Rogers and Waldron, 1989). All the individuals discussed were 40+ years and male; it is unclear from this paper whether the changes present were due to ageing, or to normal or excessive activity. No allowance was made for inherent asymmetry and the sample size was very small.

In discussing so-called "markers of occupational stress", many workers have referred to Kennedy's research on the supinator crest and fossa of the ulna (Kennedy, 1983). This paper assumes that, because the populations studied are 'known' to have thrown spears, the existence of hypertrophy of the ulna in certain areas therefore 'proves' the existence of the activity. This is a undoubtedly a circular argument. In later work, however, Kennedy discusses the problems of identifying occupational activities from the existence of certain lesions (Kennedy, 1989) stating, for example : ".....in human beings these markers are not tested experimentally. Occupational activities must be *inferred from clinical records, ethnographic accounts and archaeological and historical sources*" (p156, my italics). The dangers of such inferences have been discussed above. Kennedy also makes the following points from the literature:

1. Single occupational activities have been isolated as the cause for specific enthesopathic lesions. It has been argued elsewhere that an entire group of skeletal changes may be the result of a single activity.
2. There has been no systematic organisation of data about such markers; much of it is anecdotal and unpublished.

2.4 SUMMARY.

It is apparent that much of the previous work undertaken on activity related skeletal changes has failed to consider underlying directional asymmetry, age, sex, or sample size; in pathological change, epidemiology has often been ignored. Historical and ethnographic sources have been regarded as reliable and so has much anecdotal material. There have been few comparisons with clinical medicine.

This thesis will discuss the determination of skeletal asymmetry and the evaluation of activity related change as concurrent assessments, arguing that the former must be evaluated before the latter can be recognised. Ageing factors will be considered, together with differences between populations.

It will be demonstrated that all of these parameters have to be taken into account in determining the so-called "markers of occupational stress".

CHAPTER 3. METHODOLOGY:

MEASUREMENTS, EVALUATIONS AND INDICES.

3.1 INTRODUCTION.

The evaluation of asymmetry and the possible effects of activity on the skeleton is based on the collection and recording of a series of measurements which then allow derivation of relevant indices. The measurements and indices used in the present research are described and discussed in this chapter.

3.2 THE SAMPLES.

The sample of modern divers used as part of the radiographic analysis consisted of 49 pairs of humeri and 50 pairs of femora. The entire archaeological dry bone sample from both sites consisted of 100 pairs of humeri and 112 pairs of femora. When this archaeological sample was considered by site alone, there were 36 paired humeri from the *Mary Rose* and 64 pairs from Norwich. The matched femora from the sites consisted of 55 pairs from the *Mary Rose* and 57 pairs from Norwich. When the archaeological sample was considered by age alone, there were 47 pairs of Young Adult and 53 pairs of Mature Adult humeri. (See below (3.3) for definitions of Young and Mature Adults). The paired femora consisted of 64 pairs of Young Adults and 48 pairs of Mature Adults. Rowntree (1991) stated that, provided there are at least 30 members in each sample, then comparison of the means, standard deviations and standard errors of the samples may be undertaken with confidence. All the samples described above and used in this research thus fulfill this criterion.

3.3 SEXING AND AGEING THE ARCHAEOLOGICAL SAMPLES.

The sexing and ageing of commingled human remains can present considerable problems. Both techniques require a multi-factorial approach (Brooks, 1955), which becomes increasingly unreliable for mixed or incomplete skeletons (Krogman, 1962). The commingling of the sample from the *Mary Rose* was discussed in chapter 1, where reasons were given for the choice of the two pairs of bones used for this research. Sexing of the paired humeri and femora was based on the diameters of the heads, (Krogman 1962), and was assessed independently for each pair of bones. A multi-factorial approach was used in the sexing and ageing of the skeletal remains from the ship for the original report. This involved the assessment of sex based on the morphology of the pelvis, (innominates and sacrum), skull and longbones, and on measurements of the diameters of the heads of both bones (Krogman, 1962; Bass, 1971; Brothwell, 1981; Ubelaker, 1984). Using these criteria, all the adult and adolescent burials which survived from the ship were identified as those of males or probable males. In the archaeological sample from Norwich the paired humeri and femora were taken largely from individual burials. In this case, sexing was established by the multi-factorial method discussed above and utilising the entire skeleton. Where the pairs of bones were unassociated, sexing was based on the diameters of the heads, as for the *Mary Rose* sample.

Recent work at Christ's church, Spitalfields, has suggested that there are considerable problems in estimating the age of fully mature adults from their skeletal remains (Waldron, 1989). It would appear that there has been a tendency to over-age individuals of less than 45 years and under-age those of more than 45 years. The results of the Spitalfields work thus emphasise the problems involved in attempting to age adults of more than 25 years, particularly as these skeletal remains were post-medieval and non-archaeological in nature. Nevertheless, in order to report on or work with human skeletal remains, careful attempts using a variety of methods must be made to assign age, as well as sex, to adult individuals. In the case of sub-adults, only age can be assigned with confidence.

The criterion thought to be the most reliable for adults is that of age-related changes occurring at the pubic symphysis (Brooks, 1955; Suchey and Brooks, 1988). Other criteria that have been widely used include cranial suture closure (Ferembach *et al.*, 1980) and attrition of the molars (Brothwell, 1981). However, the former is recognised as unreliable (Brooks, 1955; Krogman, 1962), and the latter can be used only for a specific group in which a pattern of ageing based on dental eruption times can be constructed for that group (Corbett, 1984; Ubelaker, 1984). Degenerative changes in the vertebrae and at other sites have been employed as indicators of older individuals, by various workers, (Kerley, 1970; Ubelaker, 1984). Changes in the spongiosa of the proximal humerus and femur have also been utilised (Nemeskéri *et al.*, 1960, as quoted by Maat, 1987).

A considerable number of criteria were used to assign ages to 'individuals' for the original report on the 92 fairly complete skeletons from the *Mary Rose* (Stirland, 1985). These included dental eruption, Ubelaker 1984; epiphyseal closure, Ferembach *et al.*, 1980, McKern and Stewart, 1957; pubic symphseal ageing, Brooks, 1955; dental attrition, Brothwell, 1981, Miles, 1963 and cranial suture closure, Ferembach *et al.*, 1980. Since the integrity of the 'individuals' was uncertain, these multiple indicators helped to direct attention to mismatched bones; they also produced a large number of age categories (Stirland, 1985). For the purposes of the present research it was considered reasonable to assign the independent pairs of humeri and femora to broad age groups, because it was not possible to 'age' them specifically. This attribution was made by reference to the union of the proximal epiphyses of both bones, which occurs over a range of ages (Krogman, 1962; McKern and Stewart, 1957; Ubelaker, 1984). This range allows for the variation that is present in different populations, between individuals and between the sexes. The pairs of bones have been assigned to the following age groups:

Young Adult (YA) in which the epiphyseal line is clearly defined at the proximal end of the bones. In the proximal humerus, union occurs from 20-25 years, according to Ferembach *et al.*, (1980); McKern and Stewart's range (1957) is from 17/18-24+ (Stages 1-4). In the femur, the Ferembach range is from 18-21, whilst that of McKern and Stewart is from 17/18-20. In two individuals from the *Mary Rose*, the epiphyses were free or had just fused.

Mature Adult (MA) in which the proximal epiphyseal lines are clearly obliterating or are absent. Obliteration of the epiphyseal line in both bones occurs with increasing age. Thus, individuals in their late twenties and older exhibit decreasing evidence of this line. If degenerative change was also apparent at either or both articular surfaces, an individual was included in this group, (Ubelaker, 1984). There were few of these.

It is recognised that these divisions are somewhat arbitrary. Nevertheless, they do provide a clear distinction between "the young" and "the mature" age categories. It was not appropriate to use additional "very young" and "very old" categories because too few individuals in these age groups were present. The Young Adult and Mature Adult categories were also used to characterise the sample from Norwich. The group of divers all consisted of young men less than 30 years of age, and most were in their early twenties. Their ages were all included with their records and, for the purposes of this analysis, they have been treated as Young Adults. The evaluation of age from epiphyseal union on X-ray film has been demonstrated as unreliable (Krogman, 1962). Therefore, this technique has not been employed with any of the groups.

3.4 ESTIMATION OF STATURE.

Stature has been estimated, using the regression equations of Trotter (1970) for both the humerus and femur from the whole sample (see summary statistics for both bones in the Appendix). Using the same equations, stature was also calculated for the two age groups and the two archaeological sites, but for the femur alone. This will be fully discussed in chapter 6.

3.5 THE MEASUREMENTS.

3.5.1 The humerus.

Martin (1928) proposed a series of measurements and indices for various bones of the skeleton, including the humerus. Hrdlicka (1932) was interested in the special characteristics of the humerus and with the determination of variations in the bone in individual ethnic groups. He considered differences which could be attributable to sex, ageing, ethnic group, occupation and asymmetry. The standard measurements and indices of the humerus have been discussed by various other authors. Brothwell (1981) proposed three standard measurements which should be taken on archaeological material while Bass suggested five measurements, plus two indices (Bass, 1971). All of Bass's measurements and one of his indices have been used in the present study.

The role of the humerus in the operation of the shoulder has been considered in some detail. Consequently, attention has been paid to the proximal rather than the distal joint area. In evaluating this role, standard measurements have been utilized together with additional special measurements devised for this part of the investigation.

The equipment used to take the measurements on the humerus was as follows:

Standard osteometric board;
Kanon vernier calipers;
Holtain metal anthropometric tape;
Engineering profile gauge, (figure 3.1.1).
Standard millimeter rule;
Goniometer, (figure 3.1.2).

All measurements were taken in millimeters, apart from angular measurements, which were in degrees. Those of 100mm or more were taken to a tolerance of 1mm; measurements of <100mm were taken to a tolerance of 0.1mm. Thus, measurements of >100mm were made to $\pm$ 0.5mm and rounded up or down to the nearest mm; those of <100mm were made to $\pm$ 0.05mm and rounded up or down to the nearest 0.1mm. This tolerance allowed repeatability of measurements within an acceptable margin of error (see table 4.1).

The following measurements were taken on the humerus for all the groups; the measurement method is also given:

1. Figure 3.2 L. Maximum length from the superior point on the head to the most inferior point on the trochlea: osteometric board, (Martin, 1928; Hrdlička, 1932; Bass, 1971; Brothwell, 1981).
2. Figure 3.2 B1. Maximum breadth of the proximal surface including both the head and the greater tubercle, taken in the coronal plane: vernier caliper, (Martin, 1928; Bröste and Jørgensen, 1956). Sarker, 1962, includes this as one of his two "epiphyseal breadths" (*sic*) and states that the most proximal point of the head must be in contact with the bar of the sliding caliper.
3. Figure 3.2 B2. Maximum breadth of the distal articular surface including both the medial and lateral epicondyles: vernier caliper, (Martin, 1928; Bröste and Jørgensen, 1956).
4. Figure 3.2 D. Maximum diameter of the head, obtained by rotating the bone until the greatest distance is found: vernier caliper, (Martin, 1928; Bröste and Jørgensen, 1956; Bass, 1971).
5. Figure 3.2 M1 - X. Maximum diameter of the shaft, taken at the mid-point. This point is equidistant from either end and, when found, is marked on the bone

with a pencil: vernier caliper, (Martin, 1928; Hrdlička, 1932; Bröste and Jørgensen, 1956; Bass, 1971). Note that Bass illustrates the maximum diameter in the mediolateral position (1971, figure 67). This is incorrect. The maximum diameter includes the deltoid tuberosity which Bass does not illustrate. It occurs wherever the bone is widest at the mid-point.

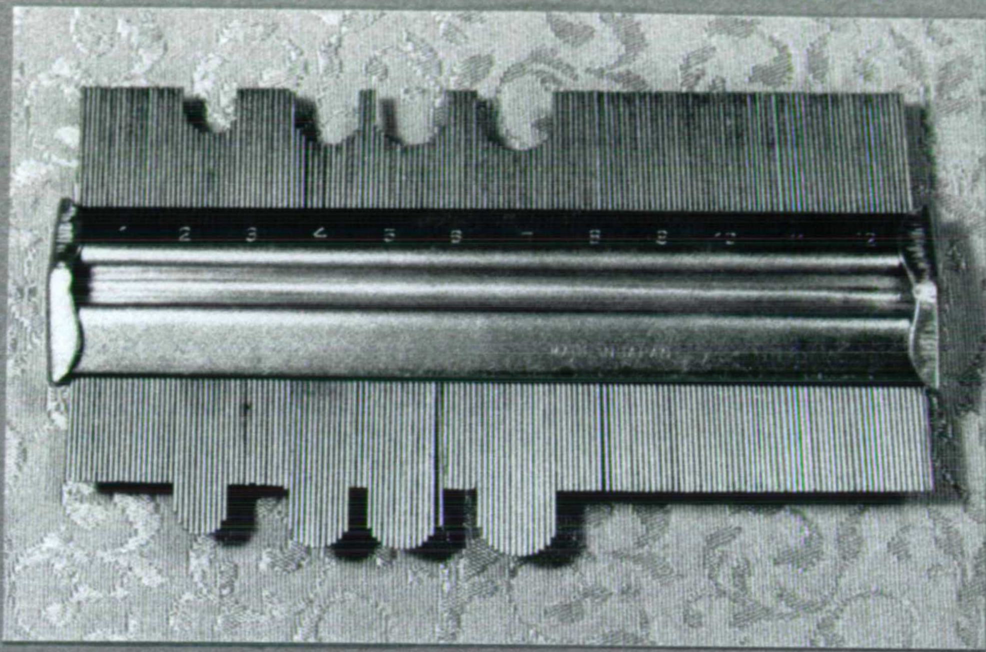
6. Figure 3.2 M2 - N. Minimum diameter of the shaft, taken at the same point as number 5. The minimum diameter is found by movement of the calipers until the smallest reading is achieved: vernier caliper, (Martin, 1928; Hrdlička, 1932; Bröste and Jørgensen, 1956; Bass, 1971).

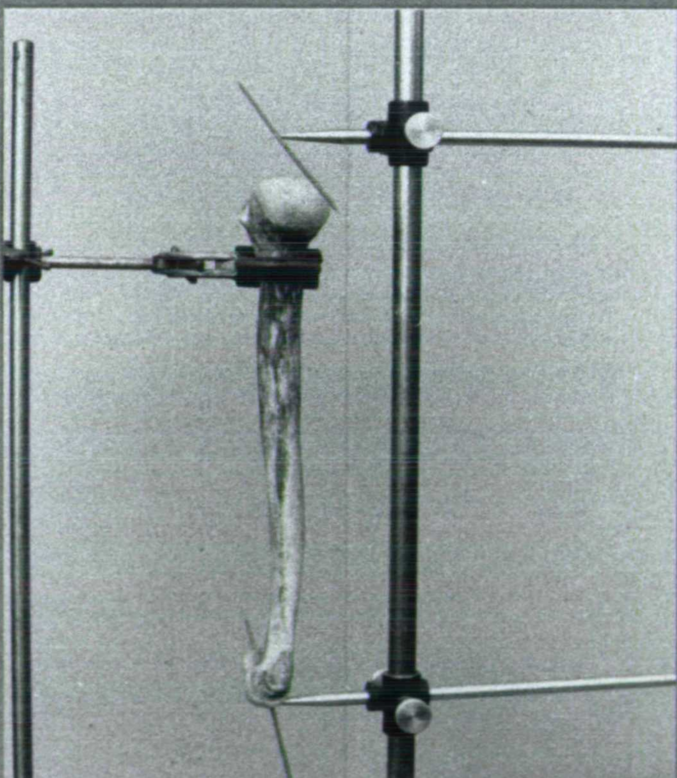
7. Least circumference of the shaft, taken distal to the deltoid tuberosity, (Martin, 1928; Bröste and Jørgensen, 1956). Bass (1971) states that this measurement is taken at the point which is "usually about a centimeter distal to the nutrient foramen" (p. 115). The foramen is variable in its position, however, and was therefore unreliable as a datum point. The measurement was taken at a point distal to the most distal point of the deltoid tuberosity or wherever the circumference was least: anthropometric Tape. This position is variable in different bones.

Figure 3.1.1: Engineering profile gauge.

Figure 3.1.2: Torsion goniometer with humerus in measurement position.

3.1.1.





3.1.2.

Figure 3.2 Measurements of the humerus.

Tanner (1964) discussed the possibility of increased activity causing thickening of the cortex of a long bone through the pull of the muscles on the periosteum. It has been stated elsewhere that "More muscle.... goes with bigger bones and a larger cortical area...." (Garn, 1970, p78). Ranked scores of the insertions of various muscles were undertaken in the present study, in order to attempt description of possible activity-related changes in the bones. Measurements were taken at the positions of the same insertions on radiographs to determine whether statistical differences in the quantity of bone present among the groups studied were occurring, and whether any differences related to the scores of the muscle insertions. The method adopted by Garn in his major work on the gain and loss of cortical bone (Garn, *ibid.*) was employed. The experimental details of the present research were as follows:

The X-ray sensitive film used was Ortho Micro, Front Screen. Fine focus was used, at a film : source distance of 100mm. For the humerus, X-rays were generated at 80 KV and beam current of 0.78 mA; for the femur, X-rays were generated at 90 KV and beam current of 0.97 mA. Two dimensions were measured. They were:

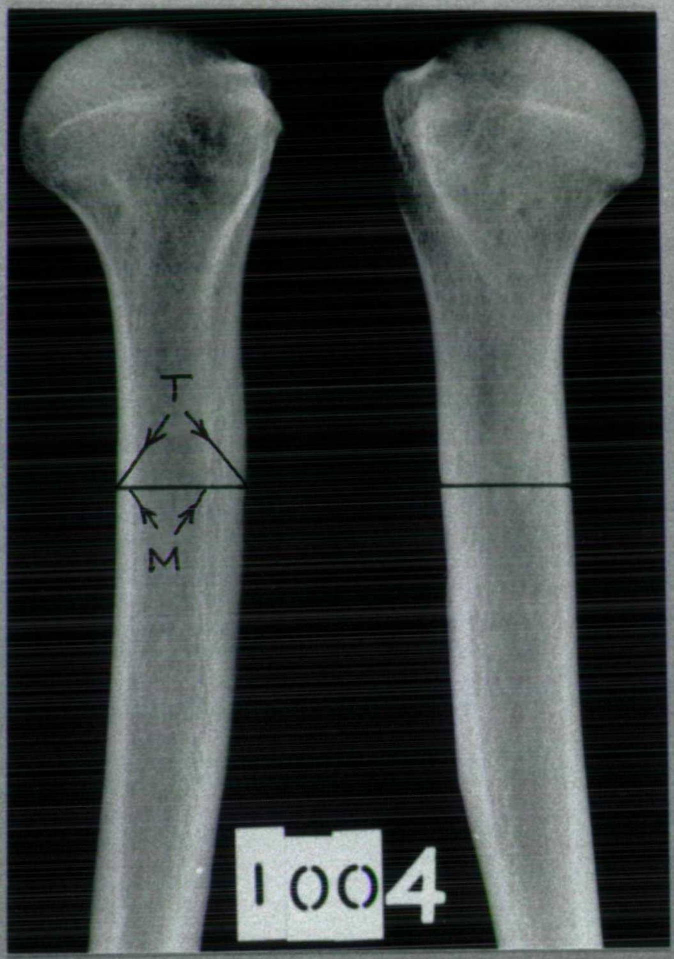
T = total subperiosteal diameter (Garn, 1970);
M = medullary cavity width (Garn, 1970). Figure 3.3.1.

The subperiosteal cortical diameter of the shaft was taken at the insertion of pectoralis major in the mediolateral view. The specific bones used for each film were placed on the processed film and the same point was marked on the long insertion of pectoralis major on each pair. In this manner, the amount of cortex was measured for each pair at the same place on the bone, thus allowing comparison between the sides.

Figure 3.3.1: Positions for X-ray measurements.

Figure 3.3.2: Positions of pins on X-rays.

3.3.1



3.3.2.

In order to attempt to determine whether there were significant differences in firstly, side, secondly, age and thirdly, between the samples both in cortical area and in percentage of cortex present, three of Garn's derivations have been applied. They are:

1. C = combined cortical thickness, (T-M)
2. Cortical Area (C.A.) $= \pi/4(T^2-M^2) = 0.785(T^2-M^2)$
3. Percent cortex (%C) = C/TX100
   This is known as "Nordin's Index" (Garn, 1970).

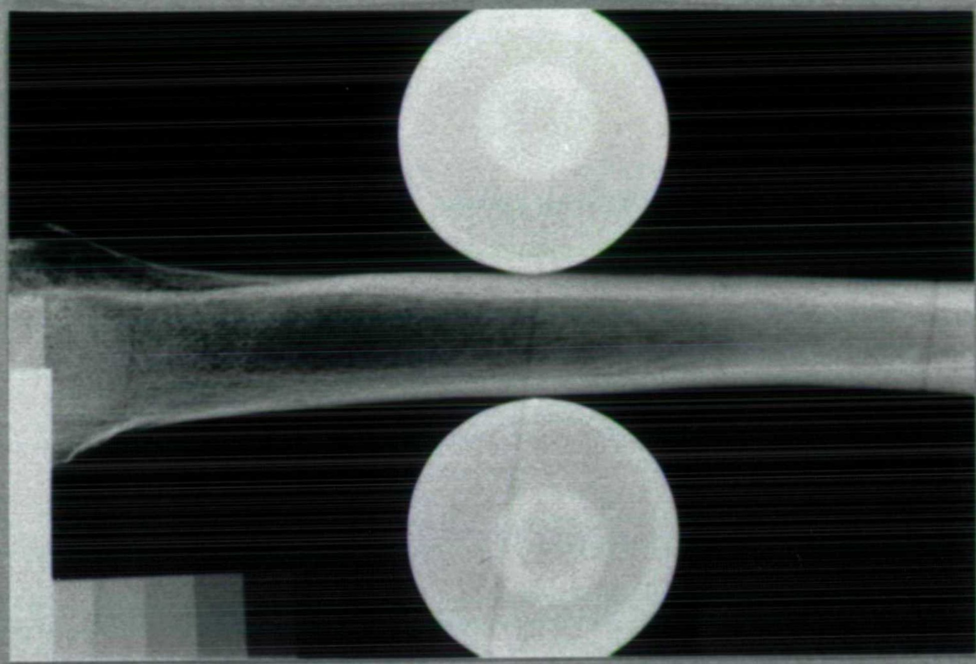
"Percent cortex" is a standardised value which describes the amount of cortex present, as does cortical area; both values are relative to the size of the individual bone. Since the amount of cortex present changes with age, (Garn, *ibid.*), it was anticipated that there might be significant differences between the younger and the older adults in the two main, archaeological, groups (YA and MA). The YA in the archaeological samples and the divers sample were also compared. Thus the YA were subdivided into the archaeological and divers groups for comparison, and the YA and MA were compared between the archaeological sites only. There were no MA in the group of divers.

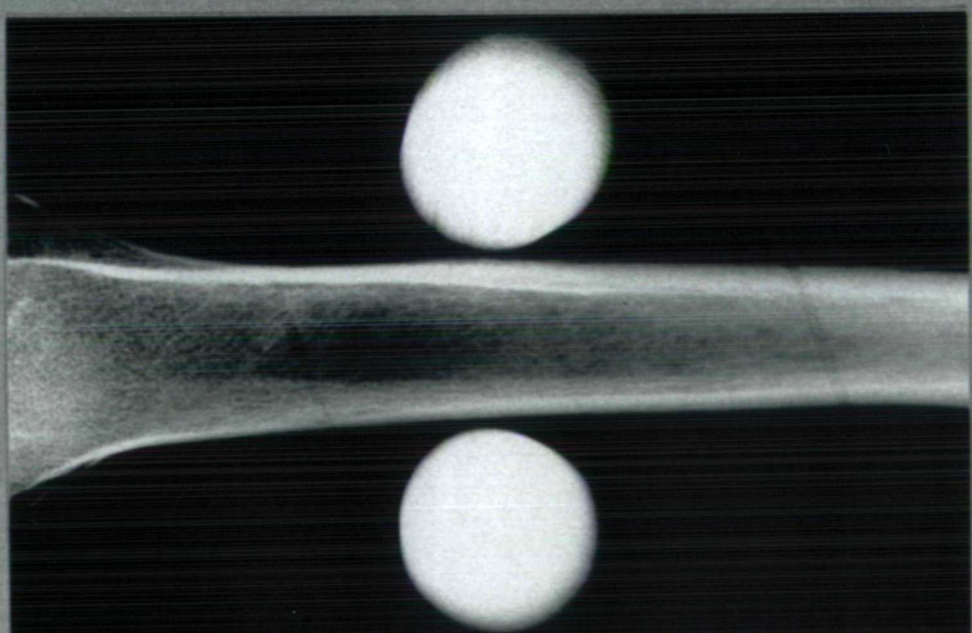
Initially, attempts were made to indicate the subperiosteal edges using pieces of metal pin, fixed around the bone with a rubber band (figure 3.3.2). If the bone was not placed in a precise orientation, however, or if it slipped a little during X-ray exposure, the markers were found to be no longer delineating the edges of the cortex. Next, cylindrical sections of wooden dowelling were positioned so that they touched the edges of the bone. The vertical beam, however, distorted the shapes into ellipses.

Figure 3.4.1: Experimental X-ray measurement positions using bottles.

Figure 3.4.2: Experimental X-ray measurement positions using dowelling rods.

3.4.1.





3.4.2.

The dowelling was then replaced by small bottles filled with a saline solution but these were also not found to be effective as markers, (figures 3.4.1 and 3.4.2). Finally, high-resolution, fine screen mammography film was employed. Clear edge definition was obtained so that it was no longer necessary to mark the edges of the bone by any external means. The most accurate and repeatable method for taking measurements was found to be with vernier calipers. The method was as follows : the calipers were placed on the outer edges of the cortex with the inner edges of the caliper arms aligned with the outer edges of the bone. This reading was then taken, to the nearest 0.1mm, and is the total subperiosteal diameter: T. To measure the medullary cavity width: M, the inner edges of the arms of the calipers were aligned with the endosteal margins at the edges of the medullary cavity and the reading was taken, again to the nearest 0.1mm. In some cases, the endosteal margin was less clearly defined, and the cancellous bone was evident at the edges of the medullary cavity (figure 3.3.1). In these cases extrapolation from the clear portion of the endosteal margin was used to estimate the measurement position.

It was not possible to transfer this technique directly for application to the radiographs of the divers, since there are differences between measurements taken on radiographs of the living and on those of dry bones. In the latter case, the radiographic measurements were taken for the dry bones at areas of muscle insertion; these are not usually visible on the radiograph and were ascertained as already discussed. Because this method was not possible with the X-ray films of the living, (no dry bones were available to lay on their films), estimates were made of the positions for the equivalent measurements. Since there was no way in which the exact equivalent positions for the radiological measurements could be achieved, it was decided to determine whether significant differences were occurring at different measuring points on the dry bone films. This was done by the statistical evaluation of 11 measurements at 1mm spacing about the estimated measurement position that is, five values at increasing distances above, and five readings at increasing distances below this position. For the humerus, the results were:

T: mean = 23.7; range = 0.8; SD = 0.29.
M: mean = 14.9; range = 1.2; SD = 0.45.

It was, therefore, obvious that the positions of the visually estimated measurements on the X-ray films were not critical within a range of $\pm$ 5mm. Measuring positions were obtained on the X-ray films from the divers by estimating a matching area of the long insertion of pectoralis major on each bone of a pair and marking it on the radiograph with a fine ink dot (see above for the dry bones). Allowances were necessary for differences in subject : film distance between the living and the dry bone subjects. In the latter case, the bone was laid directly on the film holder; in the former, the film holder is at a greater distance from the living bone due to separation by intervention from the muscle pack and other soft tissue. This results in a magnified image on the X-ray film. In order to make direct comparison between the divers and the archaeological bone measurements, the following calculation was made:

Distance of source from film = 100cm;
Estimated distance of humerus from film ~ 5cm;
Magnification ratio for humerus = 100/95 = 1.05 (Jarvis, 1989).

The measurements for each diver's bones were therefore divided by this magnification ratio to derive comparison values to the archaeological bones. Similar problems in X-ray measurements have been dealt with by Jones *et al.*, (1977).

3.5.2 Morphology of the humerus.

Measurements were made of those areas of muscle attachment on the proximal humerus which originate on the scapula and are involved in rotation and abduction of the arm. They include:

1. Horizontal dimension of the lesser tubercle: sliding caliper. One arm of the caliper was laid along the bicipital groove and the other was placed at the widest point on the tubercle (figure 3.5.1).
2. Depth of the lesser tubercle: engineering profile gauge. With the bone laid flat, a horizontal profile of the tubercle and the bicipital groove was taken and a tracing of the profile made on graph paper. The depth of the profile was measured (figure 3.5.2).

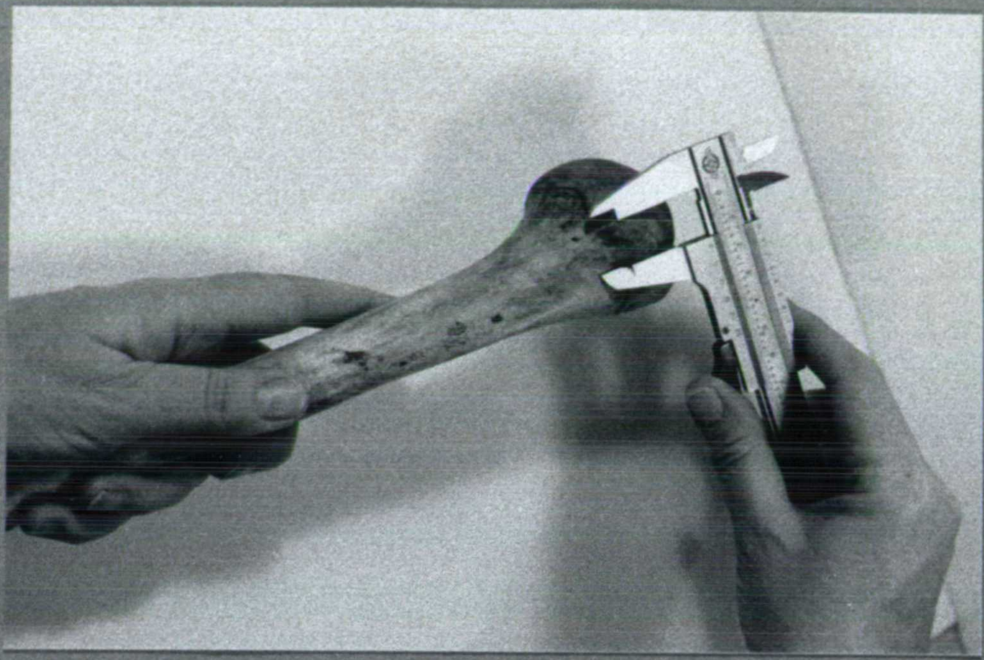
1 and 2 measure the degree of development of the insertion of subscapularis. This muscle comes from the scapula onto the lesser tubercle, protecting the anterior surface of the joint. In contraction, it rotates medially, for example when the arm is pulled across the chest.

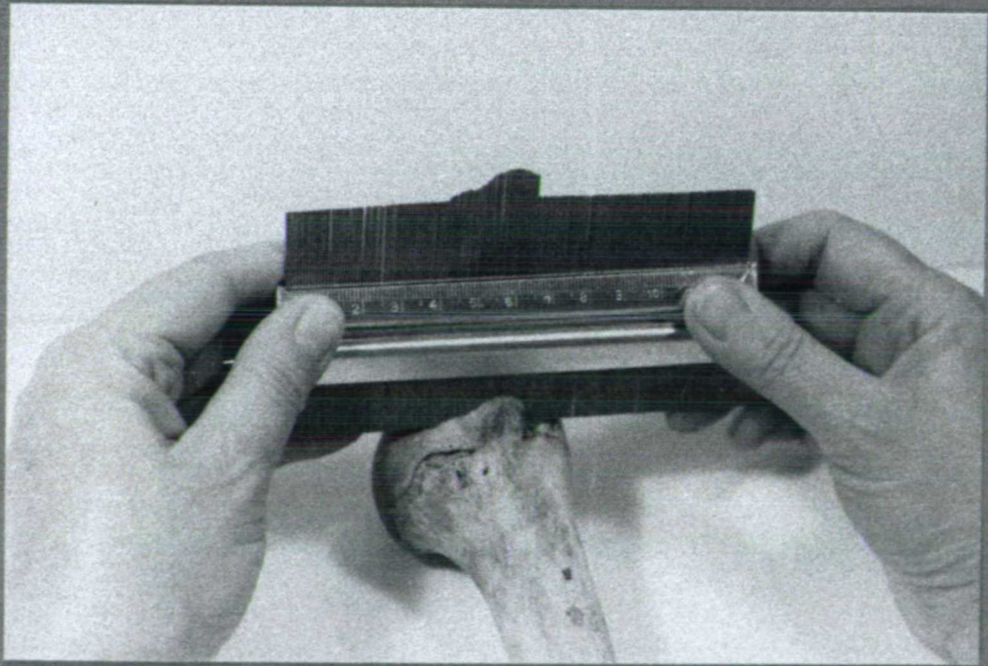
3. Horizontal dimension of the greater tubercle: vernier calipers. One arm of the calipers was laid along the bicipital groove, and the other along the most posterior limit of the tubercle. The measuring bar of the calipers was positioned to touch the top of the tubercle (figure 3.7.1).

Figure 3.5.1: Measurement of the dimensions of the humeral lesser tubercle.

Figure 3.5.2: Measurement of the profile of the humeral lesser tubercle.

3.5.1.





3.5.2.

Supraspinatus, infraspinatus and teres minor insert on this tubercle, which shows varying degrees of development. Together with subscapularis, these three muscles form the rotator cuff which acts to stabilize and maintain the integrity of the shoulder joint. All three work with deltoid to abduct and rotate the shoulder in a range of movements. It is clear that the muscles which insert on the tubercles will be employed in such activities as archery and the raising of sails. Note that such activities initiate movements in which a whole range of muscles are involved, not single ones.

It was not possible to measure other areas of attachment on the humerus. However, an attempt was made to evaluate the degree of development of the major attachments, using a score of 0-4, where 0 = no development and 4 = extensive bony build up (figure 3.6.1). Those areas evaluated were:

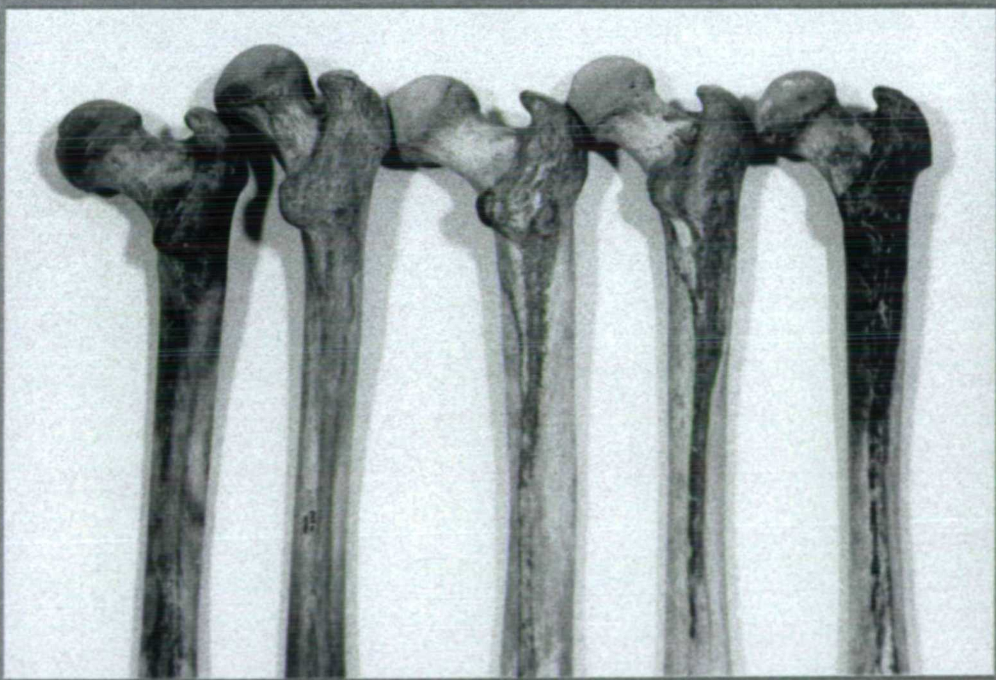
Insertion of pectoralis major on the lateral lip of the bicipital groove. This muscle is involved in flexion, medial rotation and adduction of the arm across the chest. Latissimus dorsi inserts in the bicipital groove and also assists in rotation and adduction, with some extension. Teres major acts as an adductor and medial rotator when the arm is in extension. It inserts on the medial lip of the bicipital groove. Deltoid inserts on the deltoid tuberosity. It runs over the three muscles discussed above and is involved in flexion, medial rotation, abduction and extension. All the muscles discussed in this section would be instrumental together, not singly, in a whole range of movements. These movements would be used in activities such as archery, pulling and pushing heavy cannon and raising and lowering sails.

Figure 3.6.1: Degree of development of humeral muscle insertions.

Figure 3.6.2: Degree of development of femoral muscle insertions.

Note that the degrees of development are in ascending order from left to right (0-4).

3.6.1.



3.6.2.

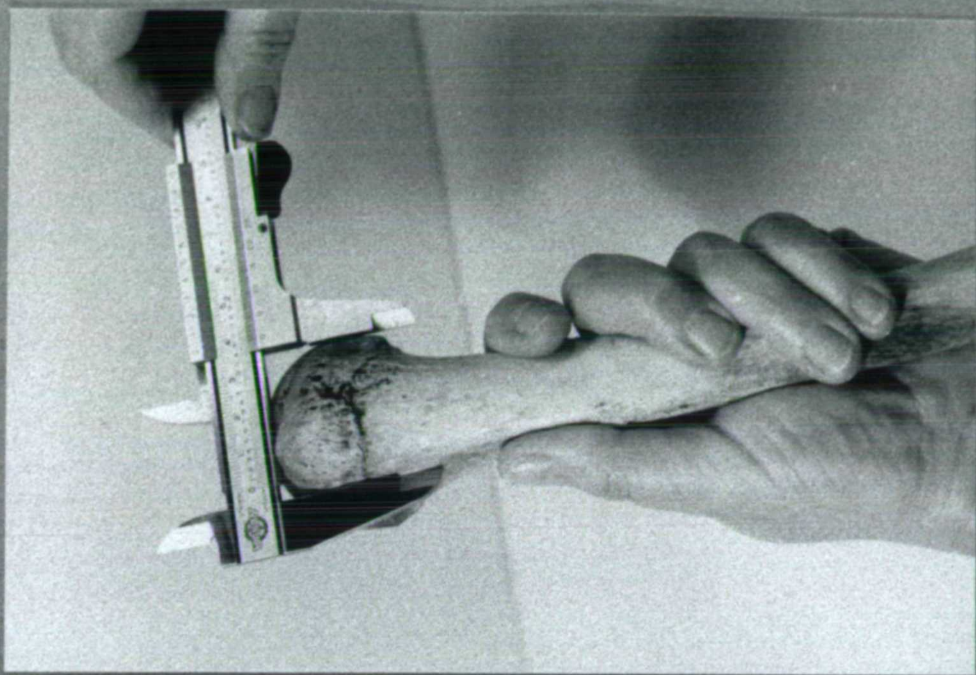
3.5.3 Angle of humeral torsion.

There has been much discussion of the angle of torsion of the humerus. Confusion occurs in the literature between the terms torsion and rotation, both of which may occur. The direction of the humeral head in many mammals is angled in relation to the plane of the distal condyles. In man, the angulation has occurred laterally, (Johnston *et al.*, 1958), although other workers argue that it is a combination of a medial torsion and a lateral rotation (Krahl and Evans, 1945). A 90° rotation of the whole limb occurs embryonically and superimposed on this rotation is a torsion of the proximal portion of the humerus. The latter increases from birth until the fusion of the proximal epiphysis (Krahl, 1976). The angle of torsion is defined as the angle between the long axes of the proximal and distal articulations. Krahl (*ibid.*) argues that torsion occurs at the proximal epiphyseal plate and is caused by the lateral and medial rotator muscles which insert proximally and distally to the plate, respectively. Principally for this reason it was decided that it was important to attempt the measurement of humeral torsion, in spite of reports that there may be a 37° range of angular variation in its expression (Krahl and Evans, 1945, p235, SD $\pm$ 8.3°).

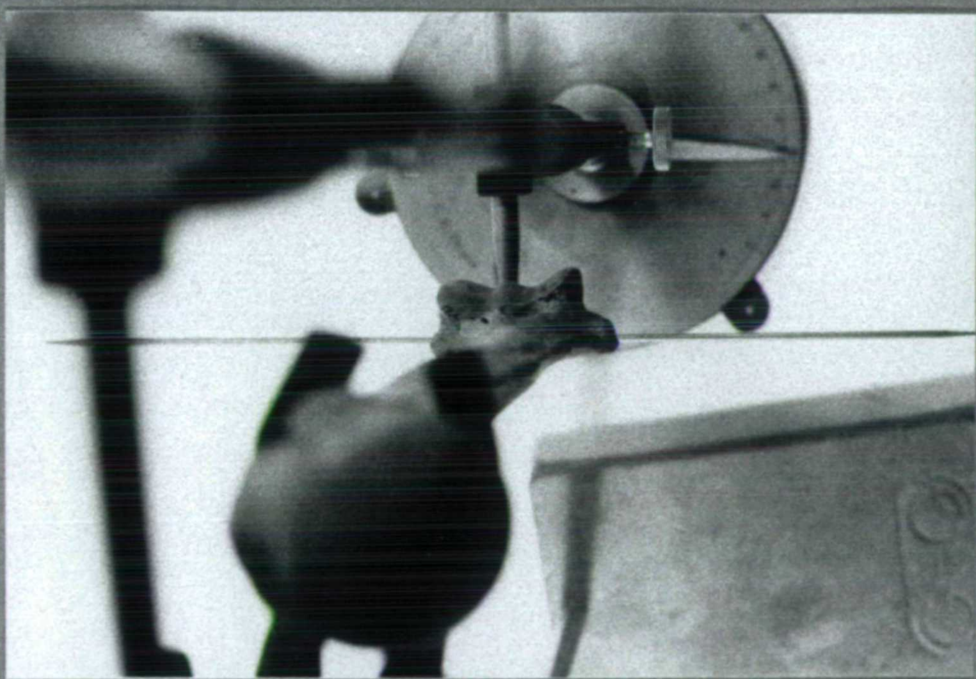
According to Krahl and Evans (1945), humeral torsion has been expressed by two different values in the literature, either as the obtuse or the acute angle. They argue that the obtuse angle is, however, incorrect, as it includes the 90° embyronic rotation, and that the acute angle should be measured. This can be done using a torsion goniometer (Sarker, 1962), (figure 3.1.2). The equipment allows this angle to be measured, with a reasonable degree of reproducibility,

Figure 3.7.1: Measurement of the dimension of the humeral greater tubercle.

Figure 3.7.2: Distal humerus in the goniometer, showing goniometer base with angular measurements.



3.7.1



3.7.2.

(Intra-observer error = 4.4%; inter-observer error = 5%. See table 4.1). The bone must be held, at the proximal one-third of the shaft, in a vertical orientation (this may be established by reference to the vertical axis of the goniometer). The bone is clamped lightly to maintain the vertical axis. When the bone is viewed directly from above, the axes which define the angle of torsion are those which bisect the head between the insertions of supraspinatus and infraspinatus (McMinn and Hutchings, 1985). In the same view, the distal articulation is bisected by a line taken directly through the medial and lateral epicondyles (figure 3.7.2). The points adopted for the proximal and distal bisections were repeatable, since they may be readily found. The true acute angle was then derived thus:

90^{o} minus the angle read from the goniometer base. This is the angle of torsion; the smaller the angle is in relation to 90^{o}, the larger the angle of torsion.

3.5.4 Entheses and Syndesmoses.

Degenerative disease of tendinous and ligamentous insertions is well documented clinically, affecting older individuals and often causing bony proliferation at the insertion sites (Resnick and Niwayama, 1981). The latter changes may also occur in young individuals, however, and involve lesions as well as proliferation; these may reflect activity stress. In the humeri from the *Mary Rose* such lesions sometimes occurred, particularly at the insertion of pectoralis major. They have been evaluated for all the groups using the following method:

Profiles of the lesions were taken using an engineering profile gauge; these were then transferred onto graph paper. The depth of the profiles was measured.

3.5.5 Humeral Indices.

These were defined as follows:

1. Mid-shaft Index: minimum diameter mid-shaft/maximum diameter midshaft x 100.
2. Robusticity Index: least circumference/maximum length x 100.
3. Tubercle Index: horizontal dimension of the lesser tubercle/horizontal dimension of the greater tubercle x 100.
4. Lesser tubercle Index: depth of the lesser tubercle/horizontal dimension of the lesser tubercle x 100.

3.5.6 The Femur.

The femur has been extensively studied by many researchers resulting in a considerable number of publications. One of the fundamental studies on this bone, by Pearson and Bell (1919), attempted all possible measurements of the femur and its various angles; this study provided the basis on which much future work has been built. For example, Ingalls (1924), suggested 35 measurements, some of which were the same as those of Pearson and Bell. Hrdlička (1934), studied the shape of the femoral shaft, using very large samples of immature and adult material. Martin (1928), Bass (1971) and Brothwell (1981) all described and discussed basic measurements of this bone, many of which have been utilized here. However, in order to provide parameters which might reflect both the asymmetry in individuals and the differences between the study groups, other measurements have been added to these basic ones. They are a selection of some already known and some which have been formulated for this study. Amongst the former, measurements of the distal shaft have been discussed by various authors.

A comprehensive discussion of the measurements of the lower femoral shaft is provided by Kennedy (1973). In this, the history of the 'Popliteal Index' first described by Manouvrier (1895, in Kennedy, 1973) is discussed at some length. Manouvrier's objective in defining the ndex was to differentiate the Pithecanthropus 1 femur from others at the distal end. Since one of the objects of this present work is to differentiate right from left bones and to express both intra- and inter-group differences, this index would seem appropriate here. However, various workers have encountered problems in the positions at which the measurements should be taken. In previous work, no differences in bone length which may affect such popliteal measurements appear to have been considered. Therefore, it was decided in the present work that standardisation should be incorporated, in order to allow for differences in the lengths of individual bones. Accordingly, the anteroposterior and mediolateral popliteal measurements were always taken at points that were one-quarter of the maximum length of the individual bone (figure 3.8).

The equipment used to take the measurements on the femur was as follows:

Standard osteometric board;
Kanon vernier calipers;
Holtain anthropometric tape;
Engineering profile gauge;
Standard millimeter rule;
Linex protractor.

Figure 3.8: Main measurements of the femur.

All measurements were taken in millimeters, apart from angular measurements, which were in degrees. Measurements of 100mm or more were taken to a tolerance of 1mm; those of <100mm were taken to a tolerance of 0.1mm. These levels of tolerance have already been discussed with reference to the humerus.

The following measurements were taken on the femur for all the groups:

1. Figure 3.8 L1. Maximum length from the top of the head to the most distal point on the medial condyle: osteometric board, (Pearson and Bell, 1919; Martin, 1928; Sarker, 1962; Bass, 1971; Kennedy, 1973; Brothwell, 1981).
2. Figure 3.8 L2. Maximum oblique or physiological length from the top of the head to the horizontal plane of the condyles, taken with both condyles against the fixed upright of the osteometric board, (Pearson and Bell, 1919; Martin, 1928; Bass, 1971; Kennedy, 1973; Brothwell, 1981).
3. Figure 3.8 A1 - P1. Subtrochanteric anteroposterior diameter, taken on the shaft just distal to the lesser trochanter and avoiding the gluteal ridge: vernier calipers, (Pearson and Bell, 1919; Martin, 1928; Sarker, 1962; Bass, 1971; Kennedy, 1973; Brothwell, 1981).
4. Figure 3.8 M1 - X1. Subtrochanteric mediolateral diameter, taken at the same level as the previous measurement but at right angles to it: vernier calipers, (References as for previous measurement).
5. Figure 3.8 A2 - P2. Maximum mid-shaft anteroposterior (pilastric) diameter, taken in the sagittal plane and equidistant from both articular surfaces: vernier calipers. The midshaft point is marked with a pencil. (Pearson and Bell, 1919; Martin, 1928; Bass, 1971; Kennedy, 1973).

Figure 3.9: Measurements of the distal femur.

6. Figure 3.8 M2 - N1. Maximum mid-shaft mediolateral (pilastric) diameter, taken at the same level as the previous measurement but at right angles to it: vernier calipers.

7. Figure 3.8 A3 - P3. Anteroposterior (popliteal) diameter taken one quarter of the maximum length of the bone, measured from the articular surface of the medial condyle. This measurement is taken with the bone lying on its lateral side with the head uppermost: vernier calipers. The one quarter point is marked with a pencil. (Pearson and Bell, 1919; Martin, 1928; Kennedy, 1973).

8. Figure 3.8 M3 - X2. Mediolateral (popliteal) diameter taken at the same point as the previous measurement but at right angles to it, so that the bone is lying on its anterior side: vernier calipers.

9. Circumference of the mid-shaft, taken at the same level as the pilastric diameters: anthropometric tape, (Martin,1928; Bass, 1971; Kennedy, 1973).

10. Figure 3.8 D. Maximum diameter of the head: vernier calipers, (Pearson and Bell, 1919; Martin, 1928; Bass, 1971; Kennedy, 1973).

11. Figure 3.9 BB. Maximum bicondylar breadth, taken parallel with the infra-condylar plane and with both condyles touching the bar of the calipers. The maximum distance between the most lateral point of the lateral condyle and the most medial point of the medial condyle is recorded: vernier calipers, (Martin, 1928; Sarker, 1962; Kennedy, 1973).

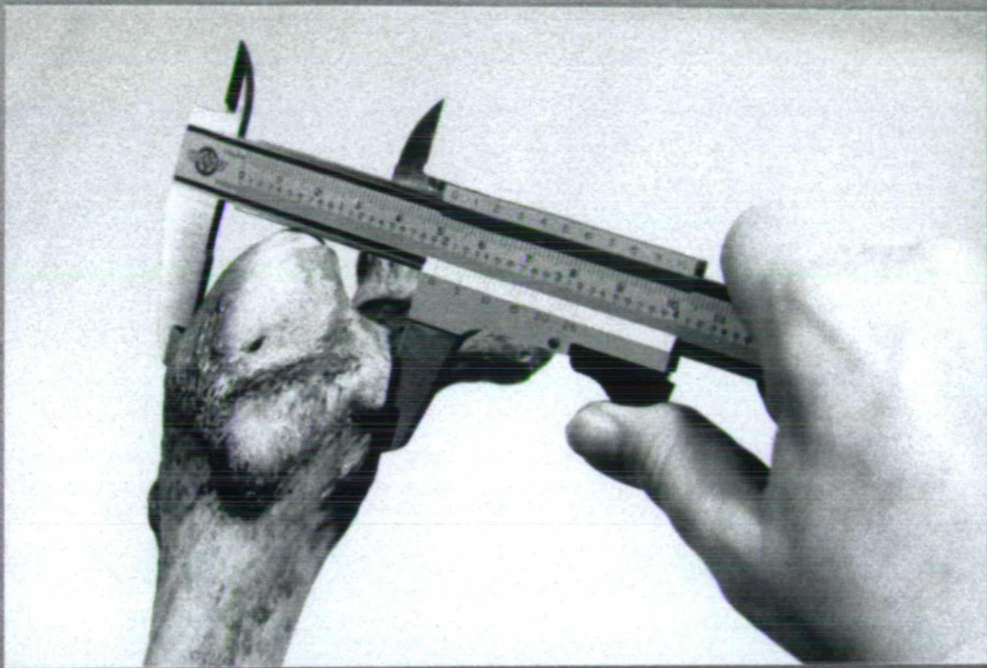
12. Figure 3.9 LC. Maximum length of the lateral condyle, taken in an anteroposterior direction and with the articular surface of the condyle touching the bar of the calipers in the infracondylar plane: vernier calipers, (Martin, 1928; Kennedy, 1973).

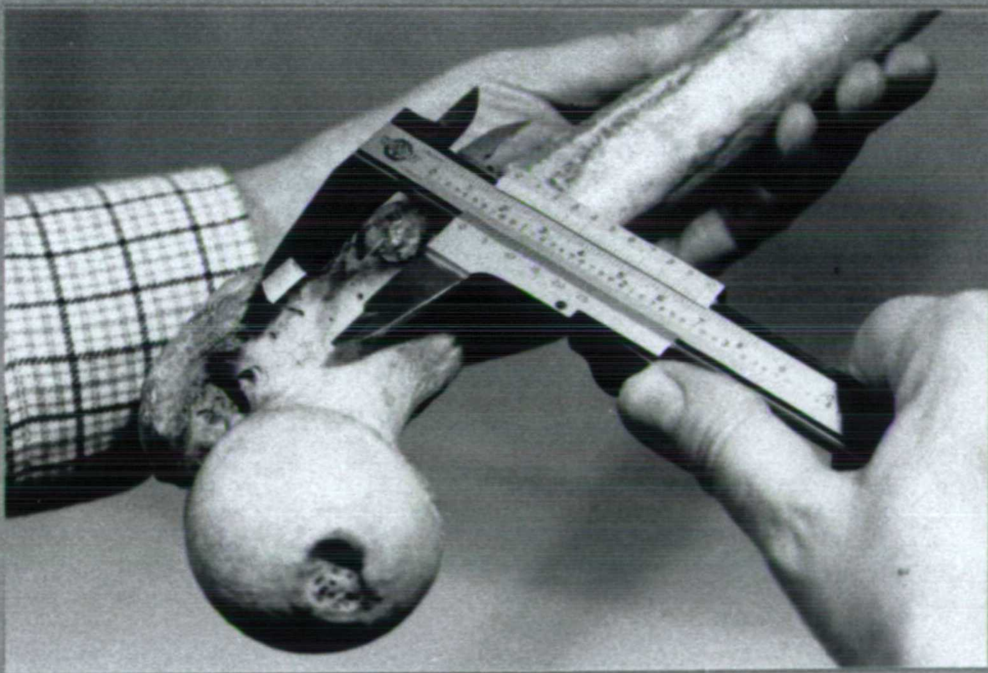
13. Figure 3.9 MC. Maximum length of the medial condyle, taken in the same manner as number 12, but for the medial condyle.

Figure 3.10.1: Measurement of the femoral greater trochanter.

Figure 3.10.2: Measurement of the femoral lesser trochanter.

3.10.1





3.10.2.

14. Figure 3.9 LB. Maximum breadth of the articular surface of the lateral condyle, taken in a mediolateral direction, without the condyle touching the caliper bar. The condylar surface is held proximally and the posterior surface of the bone faces the observer: vernier calipers, (Martin, 1928; Kennedy, 1973).
15. Figure 3.9 MB. Maximum breadth of the medial condyle, taken in the same manner as number 14.
Note that measurements 12-15 are <u>projected</u> measurements since the surfaces involved are curved.

3.5.7 <u>Morphology of the femur.</u>

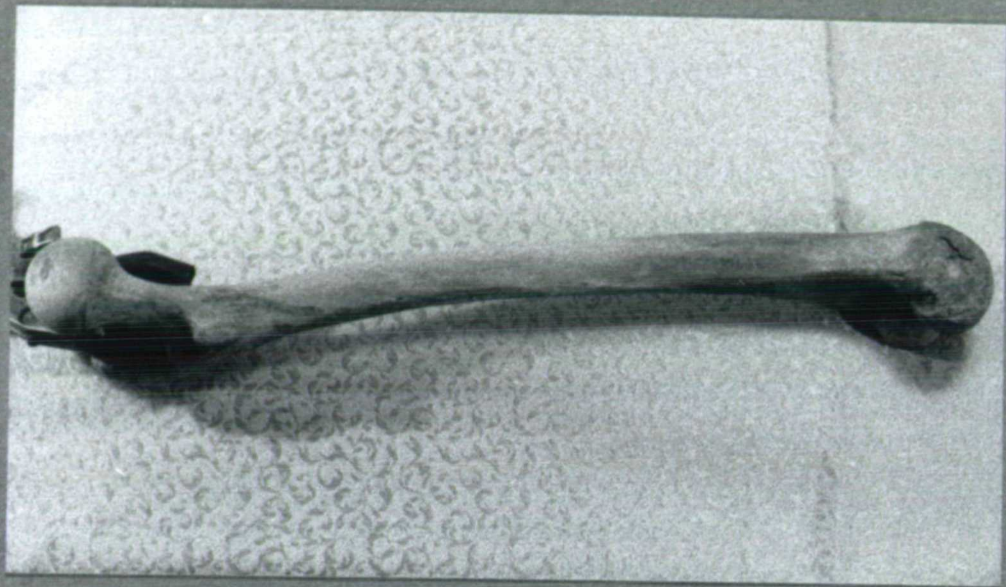
Various methods of measurement have been formulated in order to evaluate the attachments of the large muscles of the thigh on the femur, and to estimate the degree of anteroposterior bowing of the shaft. The measurements taken were:

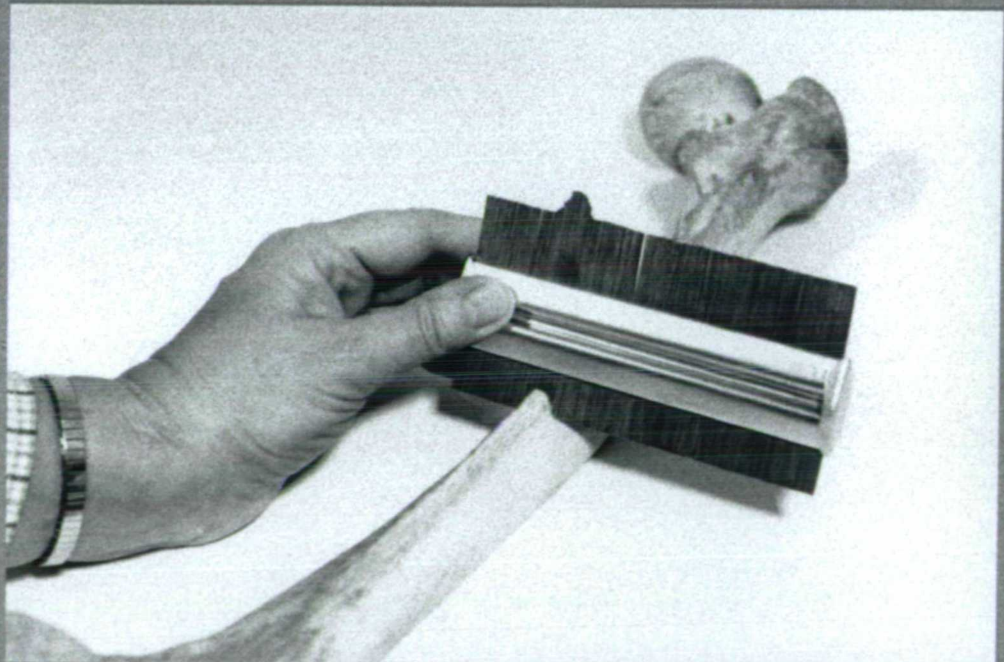
1. Figure 3.10.1. Maximum dimension of the greater trochanter, taken approximately in the sagittal plane and including the entire epiphysis : vernier calipers. The measurement was taken with the most proximal point of the trochanter resting against the horizontal bar of the calipers.
2. Figure 3.10.2. Maximum dimension of the lesser trochanter, taken in the coronal plane: vernier caliper. The measurement was taken with the horizontal bar of the calipers placed at the distal end of the trochanter and with the bone inverted.
3. Figure 3.11.1. Degree of anteroposterior bowing of the shaft, taken from a tracing. Previous measurements of the bowing of the shaft and its indices are comprehensively discussed by Kennedy (1973). The method used here is an adaptation of that of Guldberg (1905, in Pearson and Bell 1919).

Figure 3.11.1: Measurement of femoral bowing.

Figure 3.11.2: Measurement of the height of the linea aspera.

3.11.1.





3.11.2.

The bone was clamped at one end with the head, lesser trochanter and medial condyle held uppermost, and the condyles held vertically. A fine pencil was used to make a tracing along the anterior edge from the point of the subtrochanteric measurements to the point of the popliteal measurements, producing a shallow arc. The end points of this arc were joined in a chord, and both the chord and the maximum subtense from this chord to the arc was measured: clear millimeter rule, (Pearson and Bell, 1919; Kennedy, 1973). Care was taken to ensure that the bone was in the correct orientation. After experimentation, it was found easier to hold the bone in the correct orientation in every case with only one end clamped. Clamping both ends caused the bone to twist and thus distorted the arc.

4. Figure 3.11.2. Height of the linea aspera at the midpoint: engineering profile gauge. A horizontal profile of the linea aspera was taken and transferred to graph paper. The depth of the profile was measured.

It was not possible to measure other areas of attachment on the femur. However, an attempt was made to evaluate the degree of development of the attachment of those muscles involved in adduction, abduction, extension and flexion of the hip and leg. A score of 0 - 4 was used, where 0 = no development and 4 = extensive bony build up (figure 3.6.2). Those areas evaluated were:

The insertions of gluteus maximus on the gluteal tuberosity, gluteus medius and minimus on the greater trochanter and psoas major and iliacus (iliopsoas) on the lesser trochanter. The gluteal muscles are involved in extension and both lateral and medial rotation. In particular, gluteus medius and minimus work together in lateral pelvic tilt, helping to maintain the balance. Iliopsoas is a flexor, involved when bending from the hip. Their importance for those involved in activities on board a ship is obvious. The insertions and origins of the adductors and vasti groups on the linea aspera were also scored. The origins of vastus medialis and lateralis were included since, in dry bone, they cannot be distinguished from the insertions of the adductors on the linea aspera. The adductors are used to grip with the thighs, as when riding a horse or sitting astride a beam. The vastus muscles act as knee extensors. The insertion of quadratus femoris on the proximal femur was scored. This muscle is involved in lateral rotation of the thigh and would be used when drawing a longbow, for example. The insertion of the ilio-femoral ligament on the intertrochanteric line was included. This is part of the capsular attachments and is involved in stabilisation of the joint by preventing its hyperextension. The origins of gastrocnemius and plantaris on the posterior distal femur, involved in plantar flexion of the foot, as in climbing, were also included.

The repeatability of all measurements were tested for intra- and inter-observer error. The results of these tests are given in table 4.1.

3.5.8 Angle of femoral torsion.

Torsion of the femur is a normal occurrence (Dunlap *et al.*, 1953). It is a function of the axis of the femoral neck, which lies in a different plane from that of the shaft. This causes the transverse axis of the head to form an angle with the transverse axis of the distal end. This is the angle of femoral torsion (Johnston *et al.*, 1958; McMinn and Hutchings, 1985). It can occur anterior to the frontal plane, when it is known as ante-version or ante-torsion, or posterior to the frontal plane, when it is known as retro-version or retro-torsion. In the living, torsion is significant in various pathological conditions, from congenital dysplasia to prosthetic replacement. It is particularly significant in the young, where there is a rapid increase in the angle up to the beginning of weight-bearing (walking) and a gradual decrease from then until puberty (Rogers, 1934). An increase in the angle of torsion with a lessening of weight-bearing may affect individuals who have become immobilised due to trauma or disease of the bone. There appears to be an increase in the angles of both torsion and inclination (head/shaft angle) with a loss of function (Rogers, *ibid.*).

Attempts at *in vivo* measurements of femoral torsion include the use of radiographs (Rogers, 1931, 1934; Ryder and Crane, 1953; Burr *et al.*, 1982), and ultrasound and computerised tomography (Lausten *et al.*, 1989). Studies using dry bone include those of Pearson and Bell (1919), Ingalls (1924), Kingsley and Olmstead (1948), Dunlap *et al.*, (1953), Sarker (1962), Elftman (1945), Yoshioka and Cooke (1987) and Cobb (1987, 1988, unpublished M.S). In these studies most workers identify problems of measurement due to the local geometry of the femur. For example, Pearson and Bell (1919) discussed the problems involved in attempting to define points, lines and planes on bones in order to measure angles. The point was made many times, in all the literature considered, that there is a wide variation in reported results.

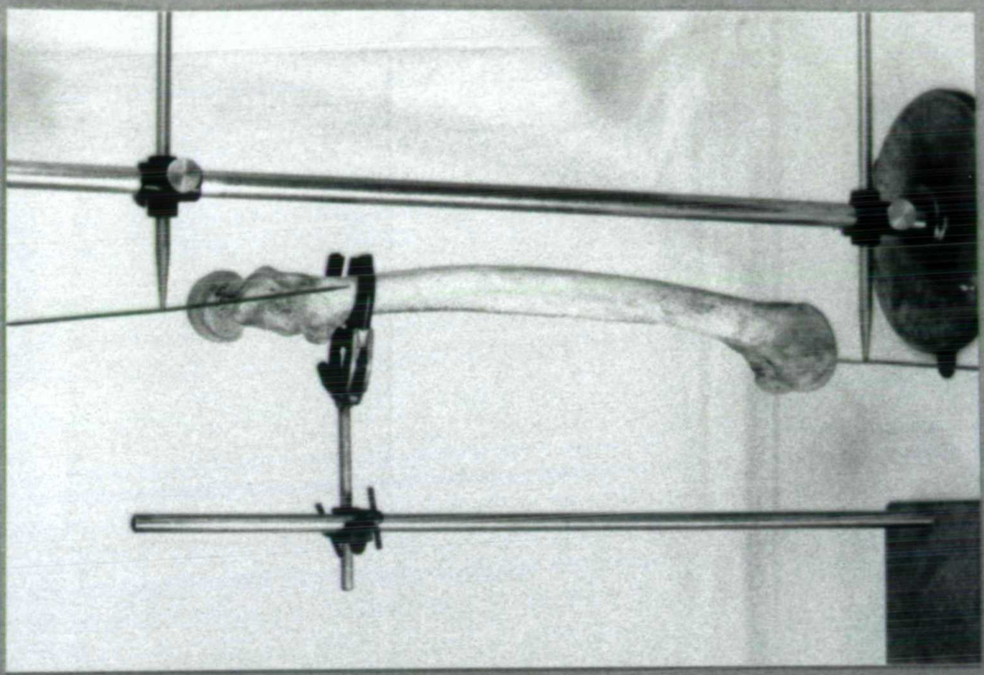
Most workers apply a technique in which the bone is placed flat on a flat surface and the angle between the transepicondylar plane and the head/neck plane is measured by use of a protractor (Kingsley and Olmstead, 1948). This technique, however, was thought by others to contribute to the problems encountered, due to the variability in the size of the epicondyles (Yoshioka and Cooke, 1987; Cobb, 1988). Sarker attempted another method, by application of a technique invented by Broste, using a goniometer (see figure 3.1). He argued that the instrument was convenient, simple to use and gave accurate results. Since it had proved useful for the humerus, it was decided to use Sarker's method for the present research. When applied to the femur, however, this method produced a high level of intra-observer error.

Attempts to apply the Kingsley and Olmstead (1948) method, using equipment devised at Arizona State University and with the bone in a horizontal position proved equally frustrating. Neither the author nor a colleague were able to repeat each other's measurements. The problem always lies in identifying fixed, reproducible points on the femoral head and neck. In order to demonstrate some of these problems, a pilot study of femoral torsion was organised and incorporated into this research. The method was as follows:

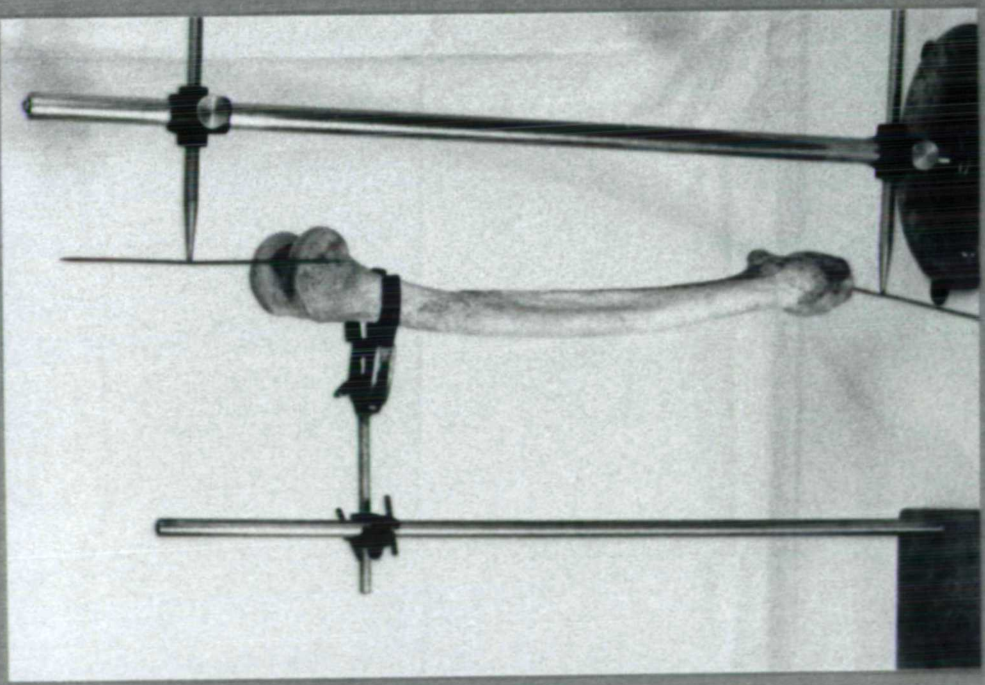
Ten pairs of femora from the *Mary Rose* were selected for the test. The torsion goniometer used for humeral torsion was utilised. Since problems had already been encountered with the conventional method, it was decided to measure each bone in two positions - in the standard orientation and also inverted, with the condyles uppermost (figures 3.12.1 and 3.12.2).

Figure 3.12.1: Vertical position of the femur for measurement of torsion.

Figure 3.12.2: Inverted position of the femur for measurement of torsion.



3.12.1



3.12.2.

Ten measurements were taken in each position (20 per bone), and for each side (40 per pair). The angle was read in the same manner as for the humerus. When the bone was in the standard position, the bottom bar was always adjusted first; when inverted, the top bar was always adjusted first. Thus, the adjustment of the bar through the condylar points was always made first. By increasing the number of readings, it was hoped to reduce the error. Each group of ten readings was averaged and the standard deviation was calculated. The results for each side were compared for each position and with each other. Finally, the readings for both positions were averaged and the standard deviations were calculated; these were then compared with the individual position readings.

The first problem encountered was that of the repeatability of the measurements. Since the angle to be read is relatively small, the position of the bone is critical. Parallax was accomodated by testing the position of the horizontal bars of the goniometer before each reading. The bone must be held vertically but, if it is clamped, the vertical axis which does not pass through the entire shaft, is warped. The bone was, therefore, suspended and allowed to swing freely in either position, rather than clamped; it then came to rest vertically. Measurements were taken with the horizontal bars bisecting the widest external point of the condyles at the distal end, and the head and neck proximally. It was the repeatability of this latter measurement that proved to be difficult, since there are no comparable anatomical points on the femoral head to those on the humerus. The angle can only be measured to the nearest $\pm 0.5^{\circ}$, although one publication (Kingsley and Olmstead, 1948) gives angular values to 0.001°. This is clearly nonsense. The results of this work are presented in table 3.1. It is obvious from this table that there was a wide range of results, even when a large number of readings were taken. The range of intra-observer error was from 42% to 5%, and the latter occurred for one measurement only. Most errors were >10%.

Problems of the repeatability of readings have been considered by very few authors. However, note that Himes (1989) emphasised that the secure replication of measurements is essential. Pearson and Bell (1919) discussed the difficulties of achieving a vertical axis and of reading the angle. Reikeras *et al.,* (1982) studied torsion radiologically and found problems with the anatomical points used in this method. Of the authors who appeared to be confident of their measurements, Sarker (1962) used the same torsion goniometer as in the present work, but clamped the bone with the "diaphyseal axis in the vertical plane" (1962, p25). The problems associated with this approach have already been discussed. Repeatability of the method is not discussed in Sarker's work and only one reading per bone was taken. Repeatability of the technique and of a single measurement are generally not discussed by authors; often, it seems to have been assumed that one reading is sufficient and that there is "bound" to be repeatability in the method. There are also statistical problems associated with the presentation of the data. Although average, or mean, values may be sufficient in some cases, it is usually desirable to include standard deviations or standard errors, as well. Few authors do this, although Elftman (1945) is one of the exceptions.

Table 3.1

FEMORAL TORSION MEASUREMENTS: REPEATABILITY STUDY.
INTRA-OBSERVER ERRORS.

No. of measure.	A		B		Both	
	L%	R%	L%	R%	L%	R%
1	27	13	14	11	22	14
2	17	11	19	28	19	31
3	11	9	5	16	9	16
4	26	9	10	19	22	31
5	25	10	29	27	28	34
6	11	15	42	16	30	22
7	14	8	12	6	14	9
8	10	10	23	35	18	36
9	25	12	12	14	20	16
10	13	11	22	14	33	14

Key: A = Femur inverted; B = Femur vertical; Both = average of the two.

The problems of measurement and the wide range of results presented in the literature (0° - 45° = Rogers 1931; 2° - 38°, with means of 11.9° to 25° = Kingsley and Olmstead, 1948) persuaded the author that it is not possible to measure femoral torsion with either sufficient reproducibility or accuracy to make the method valid. The pilot study reinforces this view.

Radiographs have been used to measure subperiosteal and medullary cavity diameters in the mediolateral view, as in the humerus. The method used was that of Garn (1970), with some modifications. As with the humerus, adjustments had to be made when measuring the radiographs of the divers. They were as follows:

1. Estimation of the midshaft measuring point.
The method used for the dry bones was the same as for the humerus: the bone which had been X-rayed was laid on its film and the midshaft point was marked on the film. However, there were no dry bones for the divers and so this point had to be estimated on their films. When their X-rays were compared, many of the femora from the *Mary Rose* sample appeared to be of a similar size to those from the divers' sample. Therefore, the X-rays from the *Mary Rose* sample were used to estimate the midshaft position on the divers films. This was done by laying the *Mary Rose* films on top of the divers' films then estimating and marking the mid-point. The femoral medullary cavity expands just distal to the mid-point. This expansion was visible on all films and was of assistance in finding the mid-point. On the films of the dry bones, the dimensions were taken at the level of the pilastric measurements in the anteroposterior view.

2. Magnification. Accomodation had to be made for the subject : film distance and for the amount of muscle pack and other intervening soft tissue. In the living, the film for the femur is at a greater distance from the subject than for the humerus and the soft tissue mass is greater. A different correction had, therefore, to be made. The magnification ratio computed for the femur was as follows:

Distance of source from film = 100 cm;
Estimated distance of femur from film ~9cm;
Magnification ratio for femur = 100/91 = 1.10
(Webster, 1991).

The measurements for each bone were then divided by this ratio to derive similar values to the archaeological bone. As with the humerus, Young Adult values were compared between the archaeological samples and the divers and between the *Mary Rose* and Norwich. Mature Adult values were also compared between the archaeological sites.

Two dimensions of the head-neck axis of the femur were also measured from X-ray films. Mid-points of the shaft, head and neck were marked on the films, taken in the anterposterior view, using a permanent, fine marker, and a clear millimeter rule. Intersecting lines were drawn up the shaft and down from the neck and head. The length of the head-neck axis was read, using a clear millimeter rule; the angle of the head on the neck was also read, using a clear protractor (Brothwell *et al*., 1968; fig 7). These results were compared between the same groups discussed above.

Certain discontinuous morphological traits of the femur, taken from Finnegan (1978) have been scored on a present/absent basis by side. They are:

Third trochanter; hypotrochanteric fossa.
Allen's fossa, Poirier's facet and plaque on the femoral neck.
Exostoses in the trochanteric fossa.

The extent to which the expression of such traits is modified by the environment is unknown. Cranial traits in particular have in the past been used to express genetic links. To what extent these or any other traits are under genetic control is also unknown. The frequency, distribution and expression of the femoral traits which have been recorded here will be discussed in chapter 6.

3.5.9 Femoral Indices.

These were defined as follows:

1. Platymeric Index: subtrochanteric anteroposterior diameter/subtrochanteric mediolateral diameter x 100.
2. Pilastric Index: mediolateral pilastric diameter/anteroposterior pilastric diameter x 100.
3. Robusticity Index: (anteroposterior diameter + mediolateral diameter) x 100/physiological length.
4. Popliteal Index: anteroposterior popliteal diameter/mediolateral popliteal diameter x 100.
5. Index of bowing: anteroposterior bowing of shaft (subtense)/chord of bowing x 100.

3.6 SUMMARY

This chapter has described the measurements obtained and indices which were derived for the humerus and femur. The whole sample was divided into separate age groups and separate sites which were then compared. The comparisons for the dry bone measurements were made between two age groups: Young Adult and Mature Adult; and between two archaeological sites: the *Mary Rose* and Magdalen Street, Norwich. Comparisons from the X-ray measurements included the sample of modern divers, all of whom were Young Adults. Certain muscle insertions were scored in order to compare them with the standardised amount of cortex present on both pairs of bones. Problems encountered with some measurements, particularly femoral torsion, were discussed.

All these measurements, derivations and rank scores were then subjected to various forms of statistical analysis which will be discussed in the following chapter.

CHAPTER 4. METHODS AND ANALYSIS:

STATISTICS.

4.1 INTRODUCTION.

The primary data on which the results are based were recorded in two ways. Initially, all measurements and rank evaluations were recorded on special forms which had been devised for this research. The measurements and evaluations, and the recording of the discontinuous morphological traits of the femur, have been discussed in chapter 3. Figures 4.1 and 4.2 are examples of the special recording forms devised for each bone. The resulting data was transferred onto 51/4 inch floppy disk, using an Amstrad PC 1512. The software used was Wordstar Professional Release 4, in the non-document mode. Because the disks and the software were compatible with the Dell machine available at the Institute of Archaeology all the data could be loaded directly from the original disks into Minitab 6.1 for analysis.

4.2 REPEATABILITY OF THE MEASUREMENTS: INTRA- AND INTER-OBSERVER ERROR.

In order that the measurements and the results on which they are based are capable of repetition and application by other workers standard biological practice was adopted. All the measurements were tested for repeatability by their originator (intra-observer = AJS), and by another observer (inter-observer = JB). The methods used were as follows:

1. Intra-observer error: Each measurement was repeated 10 times for one pair of humeri and one pair of femora, spaced over a period of about three months. The mean ($\overline{X}$) and the standard deviation (SD) was calculated for each measurement.

The formula $SD/\bar{X} x100$ was applied to each measurement. This quantity is defined as the coefficient of variation ("classic CV", Utermohle *et al.*, 1983).

2. Inter-observer error: Three different pairs of humeri and three different pairs of femora which had previously been measured by AJS (1) were measured by JB (2). Mean values ($\bar{X}$) were derived for the sum of each observer's measurements as $\bar{x} = \sum x/n$. The mean difference between the sum of each observer's measurements was derived as $\sum |x_2 - x_1|/n$. The percentage error was derived as

$$\frac{\sum |x_2 - x_1|/n}{(\bar{x}_2 + \bar{x}_1)/2} \times 100$$

Note that the Percentage error formula given in Utermohle *et al.*, 1983 is a fraction and not a percentage.

Table 4.1 presents the intra-observer reliability results and table 4.2 the inter-observer results. The repeatability of the measurements, based on these results, will be discussed in chapter 5.

Figure 4.1: Recording form for the humerus.

Figure 4.2: Recording form for the femur.

4.1

Burial: Date:

Age:

Stature:

RECORD 2: HUMERUS

	Left	Right
1. Max. L :		
2. Prox. B :		
3. Dist. B :		
4. Max. Diam. Hd. :		
5. Max. diam. midshaft :		
6. Min. diam. midshaft :		
7. Least circum. :		
Cortical Thickness:		
8. T; P:		
9. M; P:		
10. C =		
11. C.A. =		
12. % C =		
13. Horiz. L. tub :		
14. Depth L. tub :		
15. Horiz. G. tub :		
16. Pect. maj. (0-4):		
17. Lat. dor. (0-4):		
18. Teres maj. (0-4):		
19. Deltoid (0-4):		
20. Robusticity Index :		
21. Angle of Torsion :		
22. Depth of lesions :		

4.2

Burial: Date:

Age:

Stature:

RECORD 3: FEMUR

	Left	Right
1. Fe L1 :		
2. Fe L2 :		
3. Min. AP diam. :		
4. Trans. ML diam. :		
5. AP pilastric diam. :		
6. ML pilastric diam. :		
7. AP pop. diam. :		
8. ML pop. diam. :		
9. Max. circum. mid-shaft :		
10. Max. Diam. hd. :		
11. Bicond. B :		
12. L. lat. cond :		
13. L. med. cond :		
14. B. lat. cond :		
15. B. med. cond :		
16. Max. great. troch :		
17. Max. less. troch :		
18. AP bow and Chord :		
19. Lin. Asp. Ht:		
20. Glut. max. (0-4):		
21. Glut. med. (0-4):		
22. Glut. min. (0-4):		

4.2

Burial:		Date:
FEMUR contd.	Left	Right
23. Psoas maj. + Iliacus (0-4):		
24. Adds. and vastus (0-4):		
25. Quad. fem. (0-4):		
26. Iliofem. lig (0-4):		
27. Gastroc. (0-4):		
28. Plant. (0-4):		
20. Robusticity Index :		
30. Platymeric Index :		
31. Pilastric Index :		
32. Popliteal Index :		
Cortical Thickness:		
33. T; M:		
34. M; M:		
35. C =		
36. C.A. =		
37. % C =		
38. Hd./Neck L :		
39. Angle Hd. :		
40. 3rd Trochanter :		
41. Hypotrochanteric fossa:		
42. Allen's fossa :		
43. Poirier's facet :		
44. Plaque :		
45. Exos. in troch. fossa :		

TABLE 4.1

INTRA-OBSERVER RELIABILITY TEST = AJS

HUMERUS MEASUREMENT	CV	FEMUR MEASUREMENT	CV
1.Max L:	0.1	1.L1:	0.1
2.Prox.B:	0.6	2.L2:	0.1
3.Dist.B:	0.3	3.APdiam:	1.6
4.Diam.Hd:	0.6	4.MLdiam:	1.6
5.Max.MS:	2.6	5.APpil:	2.6
6.Min.MS:	1.5	6.MLpil:	0.3
7.Least C:	1.0	7.APpop:	0.6
8.Total:	1.1	8.MLpop:	0.5
9.Medul:	2.9	9.Max.C:	1.3
13.H.L.Tub:	4.8	10.Diam.Hd:	1.9
14.D.L.Tub:	8.7	11.Bicon.B:	0.2
15.H.G.Tub:	1.6	12.L.l.con:	0.4
21.Torsion:	4.4	13.L.m.con:	0.3
		14.B.l.con:	0.6
		15.B.m.con:	2.6
		16.Max.G.T:	1.2
		17.Max.L.T:	5.6
		18a.APbow:	5.9
		18b.Chord:	1.5
		19.LAH:	20.0 *
		33.Total:	0.8
		34.Medul:	3.7
		38.H/NeckL:	0.2
		39.Ang.Hd:	0.7

NOTE: All measurements are as on the recording forms in figures 4.1 and 4.2.

CV = coefficient of variation.

Asterisks * denote poor repeatability (see chapter 5).

TABLE 4.2

INTER-OBSERVER RELIABILITY TEST = JB

HUMERUS MEASUREMENT	HUMERUS ERROR	FEMUR MEASUREMENT	FEMUR ERROR
1.Max.L:	0.3%	1.L1:	0.1%
2.Prox.B:	1.3%	2.L2:	0.1%
3.Dist.B:	0.5%	3.APdiam:	2.1%
4.Diam.Hd:	0.6%	4.MLdiam:	1.9%
5.Max.MS:	1.8%	5.APpil:	2.6%
6.Min.MS:	2.6%	6.MLpil:	1.3%
7.Least C:	4.8%	7.APpop:	0.7%
8.Total:	0.8%	8.MLpop:	0.8%
9.Medul:	8.9%	9.Max.C:	1.9%
13.H.L.Tub:	10.4% *	10.Diam.Hd:	3.6%
14.D.L.Tub:	15.6% *	11.Bicon.B:	0.4%
15.H.G.Tub:	2.3%	12.L.l.con:	0.6%
21.Torsion:	5.0%	13.L.m.con:	0.9%
		14.B.l.con:	4.9%
		15.B.m.con:	4.1%
		16.Max.G.T:	2.8%
		17.Max.L.T:	11.6% *
		18a.APbow:	8.6%
		18b.Chord:	16.5% *
		33.Total:	2.5%
		34.Medul:	1.1%
		38.H/NeckL:	1.4%
		39.Ang.Hd:	2.5%

NOTE: all measurements are as on the recording forms in figures 4.1 and 4.2.

Asterisks * denote poor repeatability (see chapter 5).

4.3. STANDARDISATION OF THE MEASUREMENTS.

The fundamental analysis of this thesis is concerned with the comparison of left and right measurements of both pairs of bones, from both archaeological sites. Where comparative measurements between groups of individuals are made, it is necessary to standardise the measurements in order to allow for differences in individual sizes. The following procedure was adopted:

Each measurement taken on the left side was divided by the measurement on the right side, giving a ratio which was independant of individual size variations. Such consistent division directly indicates any asymmetry that may be present. The two angles, (humeral torsion and femoral head/neck angles), were treated in the same way, as were the derived indices.

The degree of muscular development was compared with the percentage of cortex ("Nordin's Index", see Garn, 1970, p11), and with the cortical area, from the radiographic derivations. The former indicates the mass, and the latter the area of cortex present, in relation to the size of the bone (Garn, *ibid.*).

4.4. ANALYSIS OF THE DATA.

The unprocessed data was loaded into Minitab worksheets from the primary records on the floppy disks. Initially, three worksheets were created, one for the humerus, one for the femur and one for the radiographs. These worksheets were organised by rows and columns; each individual was represented by two rows, one for each side, and the data was loaded into the columns. In order to distinguish between age groups and between archaeological sites, further worksheets were created from the original ones.

All measurements were tested for normal distribution using the ranks and correlation coefficients for each side available in Minitab (Hillson, 1990, p16-19). Those which appeared to be non-normal were subjected to further analysis, using Tookey's rootogram (Hillson, *ibid.*, p24). Using these methods, the distributions of all measurements were found to be within the normal range.

An experimental statistical null hypothesis was applied which postulated that no significant differences would occur in the values of the measurements, indices and rankings between:

a) the left and right sides;
b) the age groups selected;
c) the sites selected.

To be significant, differences were required to be at least at the 5% level of confidence, that is $p \leq 0.05$. At $p = 0.05$ there is a one in twenty probability that any differences that appear will be due to chance only, which is the lowest level that is generally acceptable (Clegg, 1982, p64).

4.5. THE TESTS.

4.5.1. The Sign Test.

The initial analysis was undertaken in order to test for differences in measurements between the left and right sides. After division of the left by the right side, the *sign test* was applied. This nonparametric test was used because the paired scores had been standardised by division and had thus become ratios; differences in direction could be established but were not further quantified (Clegg, *ibid.*). However, their levels of significance or *p* values could be derived and these values therefore indicated whether or not there were significant differences in the various measurements between the two sides. Similarly to other nonparametric tests which can be applied to numerically close pairs, the sign test can detect small biological differences which a more powerful parametric test may miss (Orton, 1991).

The sign test was applied to all comparisons between the left and right sides for the samples. These included:

a) All humeral measurements and angles for each archaeologial group. The groups were evaluated separately because of the difference in the sample sizes: there were 36 pairs of humeri from the *Mary Rose* and 64 pairs of humeri from Norwich (see chapter 3). If they had been evaluated together as a single sample, the results would have been biased by the discrepancy in the sample sizes.
b) All femoral measurements and angles for the whole sample. The femora could be evaluated together because the archaeological samples were

almost identical in size: there were 55 pairs of femora from the *Mary Rose* and 57 pairs from Norwich. Therefore, the discrepancy which was present in the humeral sample sizes was not there with the femoral samples.

c) All humeral and femoral indices, for each age group and for each archaeological site, considered separately;

d) Humeral and femoral X-ray measurements and derivations for the *Mary Rose*, Norwich and the divers, considered together;

e) Humeral and femoral X-ray measurements and derivations for the Young Adults from the three sites, considered together;

f) Humeral and femoral X-ray measurements and derivations for the Mature Adults from the *Mary Rose* and Norwich, considered together.

4.5.2. Correlations.

Correlation tables were constructed for the dry bone measurements of the humerus and the femur. These were produced in order to determine which measurements were correlated with which other measurements. A table was produced for each side for the whole sample and for each of the archaeological subsamples. Low correlations were tested for significance using critical values of Pearson's r for a two-tailed test. The tables will be found in Appendices II and III; the results will be discussed in chapter 6. A further correlation was undertaken for both bones, in order to establish whether length, as a measure of size, was positively correlated with asymmetry or not. These tables will also be presented and discussed in chapter 6.

4.5.3. The Student's t test.

Having analysed the measurements for both bones in the various samples using the sign test, it was important to reconsider the metric data in a different way. Whilst maintaining the fundamental analysis by side, a further method of determining differences due to age or between the archaeological sites was needed. In order to accomplish this, the paired measurements were split into left and right and analysed, firstly between the two age groups and secondly between the two archaeological sites. Thus, each side was evaluated separately for each measurement between the age groups and the archaeological sites, and then compared with its partner.

The test used on the data in the above analysis was the *Student's t test*. This is a powerful parametric test which is useful for scores having a normal distribution. In its Minitab form, it produces levels of significance or *p* values, thus enabling differences due to age or site to be seen and compared for each side. Paired t tests were used and applied to the following measurements:

a) All humeral and femoral measurements for each side, by age group and by archaeological site, considered separately;
b) Humeral and femoral X-ray measurements and derivations for each side by age group and by archaeological site, considered separately;
c) Humeral and femoral X-ray measurements and derivations for each side for the Young Adults (YA) between the archaeological groups and the divers. For this analysis, the YA's from both archaeological sites were put together and then compared with the

divers. Since the divers also were all YA's, they were compared only with the archaeological YA's. In this way, it was anticipated that any significant differences between the archaeological and the modern material would become apparent for the younger men.

d) Humeral and femoral X-ray measurements and derivations for each side for the Mature Adult's, (MA), between the two archaeological groups.

4.5.4. Other Tests.

The two tests discussed above were applied to the metric data, in order to detect possible asymmetries. It was necessary to use other tests in order to detect asymmetries in the ranked non-metric data and in the femoral discontinuous morphological traits. These tests were as follows:

a) The scoring of the enthesopathic lesions of the humerus and of the muscle insertions of both the humerus and the femur was analysed using the *Wilcoxon-Mann-Whitney U test*. This nonparametric test is used to analyse continuous scores having non-normal distributions. In the present case, its use was limited to the archaeological material, since it was not possible to score the lesions or the muscle insertions from the divers' radiographs. In Minitab, the Wilcoxon test produces a W value for the ranks in the smaller sample, from which a p value is derived. It was applied to the following:

a.1) Depth of any lesions occurring at the insertions of pectoralis major, latissimus dorsi and teres major on the humerus. These were examined by side for each age group and for the two archaeological sites;

a.2) Scores (0-4) for the insertions of pectoralis

major, latissimus dorsi and teres major on the humerus. These were examined by side for each age group and between the archaeological sites;
a.3) Scores (0-4) for the insertions of gluteus maximus, medius and minimus, iliopsoas, adductors and vasti muscles, quadratus femoris, gastrocnemius, plantaris and the iliofemoral ligament on the femur. These were examined by side for the whole group.

b) Part of the research was designed to look at possible relationships between the scores for the muscle insertions on both the humerus and the femur, and the derived values of both the cortical area and the percentage of cortex present in both bones from the radiographs. These relationships had to be examined by side to detect asymmetries, and a suitable test had to be applied for comparing essentially different kinds of data. The test chosen for this was *Analysis of Variance*. This is a similar test to the t test, but is suitable for comparing dissimilar groups of data. In Minitab, the test produces a graph and a *p* value for each comparison. Because of its form in this program, it was possible to compare the data by age group and by site for each side separately. It was applied to the following:

b.1) Cortical area and each muscle score for the humerus and femur, for both sides. This was used for each age group and for both archaeological sites;
b.2) Percentage of cortex and each muscle score for the humerus and femur, for both sides. This was used for each age group and for both archaeological sites.

It was then possible to examine and compare the results to see if there were differences due to asymmetry or differences due to age or differences between the archaeological sites.

c) The scoring of femoral discontinuous morphological traits on a present/absent basis required analysis by a different statistical test. The test which is most applicable to these kinds of discontinuous traits and categories is the *chi-square test*. This test was applied to the femoral discontinuous traits for each side, and for each age group and archaeological site. Both a *chi* square and a *p* value were derived.

4.6 SUMMARY.

The recording of all the data and its subsequent manipulation by the use of Minitab 6.1 has been described. Intra- and Inter-observer repeatability has been shown to be within acceptable levels; standardisation of measurements, angles and indices have been discussed. The measurements have been shown to follow a normal distribution. Significance was required to be at the $p \leqslant 0.05$ level. The six statistical tests applied to the analysis of the data have been described.

The results of most of these tests will be given in chapter 5 and discussed in chapter 6.

CHAPTER 5. RESULTS.

5.1 INTRODUCTION.

The data analyses described in chapter 4 produced a number of results in a variety of modes. The results of all the tests described in chapter 4 are presented in the present chapter in tables 5.1 - 5.16. First, however, the results of the repeatability tests are discussed.

5.2 THE REPEATABILITY TESTS.

A margin of error, or a coefficient of variation, of 5% or less was sought in the repeatability of the humeral and femoral measurements. However, a few measurements having an error of >5% but <10% were also included. An error of 10% was the maximum that was considered to be acceptable. Table 4.1 shows the intra-observer error of the measurements, calculated as a coefficient of variation (CV). For the humerus, all measurements showed a CV of less than 5, apart from #14, the depth of the lesser tubercle. Even in this case, however, the CV was less than 10 (8.7). In the inter-observer tests, (table 4.2, calculated as % error), this particular measurement was one of the two humeral measurements with a poor repeatability (error = 15.6%); the other was #13, the horizontal measurement of the lesser tubercle (error = 10.4%). These were both new measurements, specifically devised for this work and included as part of the evaluation of particular areas of muscle insertion. Their poor inter-observer reliability should be borne in mind. It appears to be due to the problem of defining the boundaries of the lesser tubercle. However, their reasonable intra-observer reliability (error <10%) has allowed them to be retained. Neither of them show any significant differences between the sides in any of the tests.

The intra-observer repeatability of the femoral measurements was also good, with one notable exception: #19, the linea aspera height, gave a CV of 20 which was unacceptable (table 4.1). This was also a new measurement, and the limits of the linea aspera were often too ill-defined to allow confident repeated use of the engineering gauge. It was, therefore, rejected from the research and no inter-observer error measurements were undertaken on it.

The femoral inter-observer tests (table 4.2) also showed a reliability of 5% or better, with three exceptions. #18, the length of the chord of bowing, was within 10% (error = 8.6%); this measurement had a CV of 5.9 in the intra-observer tests. Whilst these values are considered acceptable, those for #17 (maximum dimension of the lesser trochanter) and the subtense of the chord of bowing (#18b), are not. The former showed an error of 11.6% and the latter an error of 16.5%. The lesser trochanter dimension, #17, showed a CV of 5.6 in the intra-observer tests. However, the lesser trochanter measurement is not significant in any of the tests and its poor reliability is, therefore, of little consequence. This is not the case, however, with the bowing measurements, and they have been retained since their intra-observer reliability is reasonable. They will be discussed further in chapter 6.

5.3 THE SIGN TEST.

Analysis of asymmetry was undertaken in two ways. Initially, division of left side measurements by right side measurements was performed using the Minitab columns of data. The sign test was then applied using a hand calculator and by reference to a statistical table of percentage points for the normal distribution (Lindley and Scott, 1984). Tables 5.1 to 5.6 present the results of the sign tests for the measurements and indices. Measurements having a significant difference between the sides of $p < 0.05$ have been marked with an asterisk, thus *.

In these and all subsequent tables, the following abbreviations have been adopted:

YA = Young Adult; MA = Mature Adult.
78ON = Norwich; MR = *Mary Rose*.

TABLE 5.1

HUMERAL MEASUREMENTS: THE SIGN TEST.

The measurements are given in the numerical order shown in figure 4.1.

TABLE 5.1.1: ARCHAEOLOGICAL SAMPLE 1: MR.

No	n	r	X	V	SD	S	*p*
1	34	10	17.0	8.5	2.91	-2.4055	<0.8
2	32	16	16.0	8.0	2.83	0.0000	50
3	34	15	17.0	8.5	2.91	-0.6873	<25
4	30	9	15.0	7.5	2.74	-2.1898	<1.5
5	35	10	17.5	8.7	2.96	-2.5338	<0.6
6	34	13	17.0	8.5	2.91	-1.3746	<10
7	29	9	14.5	7.2	2.69	-2.0446	<2.1
13	34	15	17.0	8.5	2.91	-0.6873	<30
14	31	10	15.5	7.7	2.78	-1.9784	<2.4
15	34	7	17.0	8.5	2.91	-3.4364	<0.05 *
21	31	12	15.5	7.7	2.78	-1.2590	<1.2

TABLE 5.1.2: ARCHAEOLOGICAL SAMPLE 2: 78ON.

No	n	r	X	V	SD	S	*p*
1	58	12	29.0	14.5	3.81	-4.4619	<0.0005*
2	56	15	28.0	14.0	3.74	-3.4759	<0.05 *
3	51	24	25.5	12.7	3.57	-0.4202	<35
4	56	17	28.0	14.0	3.74	-2.9412	<0.2
5	58	5	29.0	14.5	3.81	-6.2992	<0.0005*
6	57	16	28.5	14.2	3.77	-3.3156	<0.05 *
7	56	5	28.0	14.0	3.74	-6.1497	<0.0005*
13	56	25	28.0	14.0	3.74	-0.8021	<25
14	46	19	23.0	11.5	3.39	-1.1799	<15
15	57	12	28.5	14.2	3.77	-4.3766	<0.001 *
21	48	21	24.0	12.0	3.46	-0.8670	<20

WHERE: n=total of + and -; r=lowest number of + or -; $\bar{X}$=mean of n; V=variance of n (0.5 of $\bar{X}$); SD=$\sqrt{}$ of V; S=standardised value = $\frac{r - \bar{X}}{SD}$

* = significant asymmetries (see chapter 6).

TABLE 5.2

FEMORAL MEASUREMENTS: THE SIGN TEST.

The measurements are given in the numerical order shown in table 4.1. All age and site samples are combined.

No	n	r	X	V	SD	S	p
1	108	38	54.0	27.0	5.20	-3.0769	<0.2
2	102	38	51.0	25.5	5.05	-2.5742	<0.5
3	101	42	50.5	25.2	5.02	-1.6932	<4.4
4	103	38	51.5	25.7	5.07	-2.6627	<0.3
5	107	44	53.5	26.7	5.17	-1.8375	<3.4
6	99	41	49.5	24.7	4.97	-1.7102	<4.4
7	108	44	54.0	27.0	5.20	-1.9230	<2.8
8	107	49	53.5	26.7	5.17	-0.8704	<15
9	97	45	48.5	24.2	4.92	-0.7114	<20
10	100	45	50.0	25.0	5.00	-1.0000	<15
11	94	35	47.0	23.5	4.85	-2.4742	<0.7
12	96	32	48.0	24.0	4.90	-3.2653	<0.06
13	97	29	48.5	24.2	4.92	-3.9634	<0.005 *
14	71	31	35.5	17.7	4.21	-1.0689	<10
15	54	20	27.0	13.5	3.67	-1.9073	<2.8
16	91	15	45.5	22.7	4.77	-6.3941	<0.0005*
17	104	48	52.0	26.0	5.09	-0.7858	<20
18a	100	42	50.0	25.0	5.00	-1.6000	<10
18b	86	34	43.0	21.5	4.64	-1.9396	<2.6
38	95	27	47.5	23.7	4.87	-4.2094	<0.005 *
39	102	35	51.0	25.5	5.05	-3.1683	<0.07

WHERE: n=total of + and -; r=lowest number of + or -; $\overline{X}$=mean of n; V=variance of n (0.5 of $\overline{X}$); SD=$\sqrt{}$ of V; S=standardised value = $\frac{r - \overline{X}}{SD}$

* = significant asymmetries (see chapter 6).

TABLE 5.3

HUMERAL RADIOGRAPHIC MEASUREMENTS: THE SIGN TEST.

The measurements are given in the numerical order shown in figure 4.1.

TABLE 5.3.1: YA FOR ALL SITES.

No	n	r	X	V	SD	S	*p*	
8	82	21	41.0	20.5	4.53	-4.4150	<0.001	*
9	79	21	39.5	19.7	4.44	-4.1666	<0.001	*
10	76	37	38.0	19.0	4.36	-0.2293	<40	
11	90	32	45.0	22.5	4.74	-2.7426	<0.3	
12	88	36	44.0	22.0	4.69	-1.7057	<4.4	

TABLE 5.3.2: MA FOR 780N AND MR ONLY.

No	n	r	X	V	SD	S	*p*	
8	51	11	25.5	12.7	3.57	-4.0616	<0.001	*
9	52	12	26.0	13.0	3.61	-3.8781	<0.005	*
10	50	21	25.0	12.5	3.54	-1.1299	<15	
11	52	25	26.0	13.0	3.61	-0.2770	<35	
12	52	16	26.6	13.0	3.61	-2.7701	<0.3	

WHERE: n=total of + and -; r=lowest number of + or -; $\bar{X}$=mean of n; V=variance of n (0.5 of $\bar{X}$); SD=$\sqrt{\ }$ of V; S=standardised value of $\frac{r - \bar{X}}{SD}$

* = significant asymmetries (see chapter 6).

TABLE 5.4

FEMORAL RADIOGRAPHIC MEASUREMENTS: THE SIGN TEST.

The measurements are given in the numerical order shown in figure 4.2.

TABLE 5.4.1: ALL AGES AND SITES COMBINED.

No	n	r	X	V	SD	S	*p*
33	115	55	57.5	28.7	5.36	-0.4664	<30
34	105	47	52.5	26.2	5.12	-1.0742	<10
35	119	54	59.5	29.7	5.45	-1.0091	<20
36	126	55	63.0	31.5	5.61	-1.4260	<10
37	125	56	62.5	31.2	5.59	-1.1628	<10

TABLE 5.4.2: YA FOR ALL SITES.

No	n	r	X	V	SD	S	*p*
33	91	45	45.5	22.7	4.77	-0.1048	<50
34	83	37	41.5	20.7	4.55	-0.9890	<15
35	96	46	48.0	24.0	4.89	-0.4089	<30
36	102	48	51.0	25.5	5.05	-0.5940	<25
37	100	45	50.0	25.0	5.00	-1.0000	<15

TABLE 5.4.3: MA FOR 780N AND MR ONLY.

No	n	r	X	V	SD	S	*p*
33	47	20	23.5	11.7	3.43	-1.0204	<15
34	45	22	22.5	11.2	3.35	-0.1492	<40
35	46	19	23.0	11.5	3.39	-1.1799	<15
36	46	18	23.0	11.5	3.39	-1.4749	<10
37	47	22	23.5	11.7	3.43	-0.4373	<30

WHERE: n=total of + and -; r=lowest number of + or -; $\overline{X}$=mean of n; V=variance of n (0.5 of $\overline{X}$); SD=$\sqrt{}$of V; S=standardised value = $\frac{r - \overline{X}}{SD}$

TABLE 5.5
HUMERAL INDICES: THE SIGN TEST.

KEY: Midshaft index = 1; Robusticity = 2; Tubercle = 3; Lesser tubercle = 4.

TABLE 5.5.1: HUMERAL INDICES BY AGE: YA AND MA.

YA	n	r	X	V	SD	S	*p*
1	46	18	23.0	11.5	3.39	-1.4740	<5
2	45	11	22.5	11.2	3.35	-3.4328	<0.01 *
3	42	14	21.0	10.5	3.24	-2.1605	<1.5
4	40	17	20.0	10.0	3.16	-0.9493	<20
MA							
1	51	21	25.5	12.7	3.57	-1.2605	<5
2	49	17	24.5	12.2	3.50	-2.1428	<1.6
3	49	17	24.5	12.2	3.50	-2.1428	<1.6
4	51	22	25.5	12.7	3.57	-0.9804	<20

TABLE 5.5.2: HUMERAL INDICES BY SITE: MR AND 780N.

MR	n	r	X	V	SD	S	*p*
1	36	18	18.0	9.00	3.00	0.00	50
2	36	18	18.0	9.00	3.00	0.00	50
3	35	14	17.5	8.75	2.96	-1.1824	<10
4	35	13	17.5	8.70	2.95	-1.5203	<10
780N							
1	61	21	30.5	15.2	3.90	-2.4359	<0.7
2	58	10	29.0	14.5	3.81	-4.9869	<0.0005 *
3	56	16	28.0	14.0	3.74	-3.2085	<0.07
4	56	23	28.0	14.0	3.74	-1.3369	<10

WHERE: n=total of + and -; r=lowest number of + or -; $\overline{X}$=mean of n; V=variance of n (0.5 of $\overline{X}$); SD= $\sqrt{\ }$ of V; S=standardised value = $\frac{r - \overline{X}}{SD}$

* = significant asymmetries (see chapter 6).

TABLE 5.6

FEMORAL INDICES: THE SIGN TEST.

KEY: *Platymeric index = 1; Pilastric = 2; Robusticity = 3; Popliteal = 4; Bowing = 5.*

TABLE 5.6.1: ALL AGES AND SITES COMBINED.

No	n	r	$\bar{X}$	V	SD	S	*p*	
1	111	36	55.5	27.7	5.26	-3.7072	<0.01	*
2	109	38	54.5	27.2	5.22	-3.1069	<0.07	
3	110	46	55.0	27.5	5.24	-1.7175	<4.4	
4	110	47	55.0	27.5	5.24	-1.5267	<5	
5	105	42	52.5	26.2	5.12	-2.0508	<2	

TABLE 5.6.2: FEMORAL INDICES BY AGE: YA AND MA.

YA	n	r	$\bar{X}$	V	SD	S	*p*
1	63	21	31.5	15.7	3.97	-2.6448	<0.5
2	62	23	31.0	15.5	3.94	-2.0304	<2.2
3	63	22	31.5	15.7	3.97	-2.3929	<0.9
4	63	26	31.5	15.7	3.97	-1.3854	<5
5	58	21	29.0	14.5	3.81	-2.0997	<1.8
MA							
1	48	15	24.0	12.0	3.46	-2.6011	<0.5
2	47	15	23.5	11.7	3.43	-2.4781	<0.7
3	47	23	23.5	11.7	3.43	-0.1458	<45
4	47	21	23.5	11.7	3.43	-0.7289	<25
5	47	20	23.5	11.7	3.43	-1.0204	<15

TABLE 5.6.3: FEMORAL INDICES BY SITE: MR AND 780N.

MR	n	r	$\overline{X}$	V	SD	S	*p*
1	55	18	27.5	13.7	3.71	-2.5606	<0.6
2	54	20	27.0	13.5	3.67	-1.9073	<2.9
3	55	25	27.5	13.7	3.71	-0.6738	<30
4	54	20	27.0	13.5	3.67	-1.9073	<2.9
5	55	24	27.5	13.7	3.71	-1.9434	<20
780N							
1	56	18	28.0	14.0	3.74	-2.6738	<0.4
2	55	18	27.5	13.7	3.71	-2.5606	<0.6
3	55	25	27.5	13.7	3.71	-0.6738	<30
4	56	27	28.0	14.0	3.74	-0.2674	<0.4
5	50	18	25.5	12.5	3.53	-1.9830	<2.4

WHERE: n=total of + and -; r=lowest number of + or -; $\overline{X}$=mean Of n; V=variance of n (0.5 of $\overline{X}$); SD=$\sqrt{}$ of V; S=standardised value = $\frac{r - \overline{X}}{SD}$

5.4 THE t TESTS.

For the purposes of presentation in this chapter, the results of the t tests have been converted into tables from their Minitab form. In each case, the results for the left side are given first, both for the two age groups and for the sites. A relevant key for each group will be found on the title page for a specific test. It should be noted that the *p* value is the final figure in each table; where this value indicates a significant difference between the ages or the sites, it has been given an asterisk, thus *. Tables 5.7 to 5.12 present the results of the t tests for measurements for each side, by age group and archaeological site separately, and for all measurements and derivations from the X-rays, as described in chapter 4. The measurements are presented in the same order as they were for the sign tests.

The application of the tests to the data generated large numbers of results. Approximately half of these results showed no significant asymmetric differences between the age groups and the archaeological sites. Accordingly, the following procedure was adopted:

All results (significant and non-significant) have been included from the measurements for each side, by age group and archaeological site, in order to demonstrate the application of the test and its results. In the case of the t tests for the X-ray measurements, however, only the significant ones have been included in most cases. This course has also been adopted for the results of the other tests which are to follow. The non-significant results of the t tests are as follows:

Humeral X-ray measurements and derivations for the MA from the archaeological sites, by side.

Femoral X-ray measurements and derivations for the MA from the archaeological sites, by side.

The results of the t tests will be discussed in chapter 6.

TABLE 5.7

TWO SAMPLE t TESTS FOR HUMERAL DIMENSIONS.

The measurements are given in the numerical order shown in figure 4.1.
KEY: N = number in sample; $\overline{X}$ *= mean; SD = standard deviation; SE = standard error of mean; T = t value;* p *= level of significance.*

TABLE 5.7.1: LEFT SIDE BY AGE.

No	Age	N	$\overline{X}$	SD	SE	T	p
1	YA	46	327.4	14.6	2.2	0.19	0.85
	MA	53	326.9	15.4	2.1		
2	YA	42	50.57	2.59	0.40	-0.97	0.33
	MA	50	51.06	2.20	0.31		
3	YA	45	63.60	3.91	0.58	-0.77	0.45
	MA	48	64.14	2.68	0.39		
4	YA	44	46.24	2.74	0.41	-1.31	0.20
	MA	50	46.91	2.18	0.31		
5	YA	46	22.42	1.46	0.22	-2.11	0.037 *
	MA	51	23.07	1.57	0.22		
6	YA	46	19.37	1.64	0.24	0.20	0.84
	MA	51	19.31	1.36	0.19		
7	YA	47	68.41	4.34	0.63	-0.95	0.35
	MA	51	69.24	4.25	0.59		
13	YA	43	16.03	2.12	0.32	-0.32	0.75
	MA	52	16.17	1.84	0.26		
14	YA	41	7.94	1.53	0.24	-1.22	0.23
	MA	51	8.30	1.23	0.17		
15	YA	45	33.89	1.93	0.29	-2.79	0.007 *
	MA	49	34.92	1.64	0.23		
21	YA	43	78.86	4.27	0.65	-0.81	0.42
	MA	49	79.59	4.41	0.63		

TABLE 5.7.2: RIGHT SIDE BY AGE.

No	Age	N	$\bar{X}$	SD	SE	T	p
1	YA	46	329.3	14.4	2.1	-0.08	0.94
	MA	53	329.6	14.8	2.0		
2	YA	42	50.92	2.78	0.43	-1.30	0.20
	MA	50	51.58	1.98	0.28		
3	YA	46	64.01	3.59	0.53	-0.06	0.95
	MA	48	64.05	2.98	0.43		
4	YA	44	46.77	2.60	0.39	-1.28	0.20
	MA	50	47.38	1.91	0.27		
5	YA	46	23.38	1.50	0.22	-0.97	0.33
	MA	51	23.70	1.76	0.25		
6	YA	46	19.89	1.79	0.26	0.85	0.40
	MA	51	19.60	1.45	0.20		
7	YA	47	70.13	4.07	0.59	-0.57	0.57
	MA	51	70.62	4.45	0.62		
13	YA	43	15.91	2.54	0.39	-0.38	0.70
	MA	52	16.09	1.87	0.26		
14	YA	41	8.13	1.39	0.22	-0.44	0.66
	MA	51	8.27	1.46	0.20		
15	YA	45	34.95	2.19	0.33	-2.00	0.05 *
	MA	49	35.80	1.92	0.27		
21	YA	43	77.74	4.70	0.72	-1.73	0.09
	MA	49	79.31	3.86	0.55		

TABLE 5.7.3: LEFT SIDE BY SITE.

No	Site	N	$\overline{X}$	SD	SE	T	*p*
1	780N	63	326.4	15.3	1.9	-0.68	0.50
	MR	36	328.5	14.5	2.4		
2	780N	58	50.54	2.44	0.32	-1.63	0.11
	MR	34	51.35	2.23	0.38		
3	780N	58	63.51	3.43	0.45	-1.43	0.16
	MR	35	64.49	3.10	0.52		
4	780N	60	46.23	2.60	0.34	-2.05	0.043 *
	MR	34	47.24	2.09	0.36		
5	780N	61	22.68	1.67	0.21	-0.72	0.47
	MR	36	22.91	1.32	0.22		
6	780N	61	19.24	1.55	0.20	-0.87	0.38
	MR	36	19.51	1.40	0.23		
7	780N	62	68.47	4.43	0.56	-1.17	0.25
	MR	36	69.49	4.02	0.67		
13	780N	60	16.03	2.07	0.27	-0.50	0.62
	MR	35	16.23	1.80	0.30		
14	780N	57	8.15	1.39	0.18	0.10	0.92
	MR	35	8.12	1.37	0.23		
15	780N	59	34.07	1.93	0.25	-2.66	0.009 *
	MR	35	35.03	1.56	0.26		
21	780N	57	79.46	4.05	0.54	0.56	0.58
	MR	35	78.91	4.81	0.81		

TABLE 5.7.4: RIGHT SIDE BY SITE.

No	Site	N	$\overline{X}$	SD	SE	T	*p*
1	780N	63	328.9	14.9	1.9	-0.53	0.60
	MR	36	330.5	14.1	2.3		
2	780N	58	51.20	2.43	0.32	-0.44	0.66
	MR	34	51.42	2.35	0.40		
3	780N	58	63.59	3.34	0.44	-1.67	0.10
	MR	36	64.72	3.10	0.52		
4	780N	60	46.93	2.35	0.30	-0.96	0.34
	MR	34	47.39	2.11	0.36		
5	780N	61	23.64	1.70	0.22	0.73	0.47
	MR	36	23.39	1.55	0.26		
6	780N	61	19.68	1.49	0.19	-0.46	0.65
	MR	36	19.84	1.82	0.30		
7	780N	62	70.57	4.32	0.55	0.56	0.57
	MR	36	70.07	4.19	0.70		
13	780N	60	15.98	2.08	0.27	-0.16	0.88
	MR	35	16.06	2.39	0.40		
14	780N	57	8.01	1.44	0.19	-1.75	0.08
	MR	35	8.53	1.35	0.23		
15	780N	59	35.14	2.24	0.29	-1.61	0.11
	MR	35	35.81	1.77	0.30		
21	780N	57	79.14	3.65	0.48	1.49	0.14
	MR	35	77.66	5.15	0.87		

TABLE 5.8

TWO SAMPLE t TESTS FOR FEMORAL DIMENSIONS

The measurements are given in the numerical order shown in figure 4.2.
KEY: N = number in sample; $\bar{X}$ = mean; SD = standard deviation; SE = standard error of mean; T = t value; p = level of significance.

TABLE 5.8.1: LEFT SIDE BY AGE.

No	Age	N	$\bar{X}$	SD	SE	T	*p*
1	YA	64	452.7	21.9	2.7	-0.83	0.41
	MA	48	456.1	20.9	3.0		
2	YA	63	450.8	21.0	2.6	-0.58	0.57
	MA	48	453.1	20.6	3.0		
3	YA	64	27.48	2.29	0.29	-0.52	0.60
	MA	48	27.71	2.33	0.34		
4	YA	64	34.62	2.68	0.33	-1.88	0.06
	MA	48	35.53	2.45	0.35		
5	YA	63	29.08	2.29	0.29	-1.04	0.30
	MA	47	29.60	2.81	0.41		
6	YA	63	28.24	1.81	0.23	-2.54	0.01 *
	MA	47	29.19	2.05	0.30		
7	YA	63	30.13	2.01	0.25	-1.32	0.19
	MA	47	30.67	2.19	0.32		
8	YA	63	34.83	2.59	0.33	-2.01	0.05 *
	MA	47	35.89	2.87	0.42		
9	YA	63	90.88	5.34	0.67	-1.96	0.05 *
	MA	47	93.05	6.06	0.88		
10	YA	60	48.13	2.54	0.33	-2.72	0.01 *
	MA	46	49.39	2.24	0.33		

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No	Age	N	$\overline{X}$	SD	SE	T	*p*
11	YA	57	81.30	3.88	0.5	-1.78	0.08
	MA	43	82.63	3.52	0.54		
12	YA	55	62.44	3.07	0.41	-1.35	0.18
	MA	47	63.24	2.92	0.43		
13	YA	56	63.15	3.27	0.44	-1.05	0.30
	MA	46	63.87	3.52	0.52		
14	YA	40	30.19	1.37	0.22	-2.10	0.04 *
	MA	34	31.02	1.93	0.33		
15	YA	30	27.31	2.10	0.38	-0.63	0.53
	MA	28	27.62	1.68	0.32		
16	YA	52	44.97	2.66	0.37	-1.89	0.06
	MA	39	46.17	3.23	0.52		
17	YA	64	18.85	2.02	0.25	0.20	0.84
	MA	45	18.78	1.97	0.29		
18a	YA	58	242.9	13.6	1.8	0.39	0.70
	MA	47	241.9	13.8	2.0		
18b	YA	58	7.43	2.16	0.28	1.46	0.15
	MA	47	6.83	2.04	0.30		
38	YA	63	82.64	6.43	0.81	-1.45	0.15
	MA	48	84.29	5.55	0.80		
39	YA	63	126.9	5.77	0.73	-0.70	0.49
	MA	48	127.7	6.21	0.90		
Height for left side only:							
	YA	128	169.5	0.05	0.00	-1.01	0.31
	MA	96	170.2	0.05	0.00		

TABLE 5.8.2: RIGHT SIDE BY AGE.

No	Age	N	$\overline{X}$	SD	SE	T	*p*
1	YA	64	451.1	22.6	2.8	-0.78	0.44
	MA	48	454.4	21.6	3.1		
2	YA	63	449.1	21.8	2.7	-0.59	0.56
	MA	48	451.6	21.8	3.1		
3	YA	64	27.57	2.18	0.27	-0.86	0.39
	MA	48	27.91	1.89	0.27		
4	YA	64	34.18	2.60	0.33	-1.53	0.13
	MA	48	34.92	2.44	0.35		
5	YA	63	29.36	2.51	0.32	-1.54	0.13
	MA	47	30.12	2.64	0.38		
6	YA	63	28.10	1.83	0.23	-2.36	0.02 *
	MA	47	28.91	1.73	0.25		
7	YA	63	29.97	1.92	0.24	-1.54	0.13
	MA	47	30.58	2.16	0.31		
8	YA	63	34.84	2.65	0.33	-2.01	0.05 *
	MA	47	35.97	3.09	0.45		
9	YA	63	90.99	5.94	0.75	-2.08	0.04 *
	MA	47	93.30	5.65	0.82		
10	YA	60	48.28	2.72	0.35	-2.23	0.03 *
	MA	46	49.37	2.30	0.34		

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No	Age	N	$\overline{X}$	SD	SE	T	*p*
11	YA	57	81.56	3.98	0.53	-1.98	0.05 *
	MA	43	82.99	3.28	0.50		
12	YA	55	62.80	3.11	0.42	-2.14	0.03 *
	MA	47	64.12	3.12	0.45		
13	YA	56	62.24	3.59	0.48	-1.64	0.10
	MA	46	63.39	3.48	0.51		
14	YA	40	30.41	1.71	0.27	-1.62	0.11
	MA	34	31.08	1.81	0.31		
15	YA	30	26.87	2.43	0.44	-1.54	0.13
	MA	29	27.72	1.74	0.32		
16	YA	52	46.76	3.27	0.45	-1.51	0.14
	MA	39	47.77	3.08	0.49		
17	YA	64	18.66	1.58	0.20	-0.69	0.49
	MA	45	18.87	1.63	0.24		
18a	YA	58	240.4	15.9	2.1	-0.44	0.66
	MA	47	241.7	12.9	1.9		
18b	YA	58	7.68	2.37	0.31	1.24	0.22
	MA	47	7.16	1.93	0.28		
38	YA	63	81.34	6.08	0.77	-1.03	0.30
	MA	48	82.57	6.34	0.91		
39	YA	63	125.3	6.73	0.85	-0.34	0.73
	MA	48	125.7	6.50	0.94		

TABLE 5.8.3: LEFT SIDE BY SITE.

No	Site	N	$\overline{X}$	SD	SE	T	*p*
1	780N	57	449.1	22.0	2.9	-2.61	0.01 *
	MR	55	459.4	19.6	2.6		
2	780N	56	446.8	21.1	2.8	-2.61	0.01 *
	MR	55	456.8	19.2	2.6		
3	780N	57	27.23	2.39	0.32	-1.64	0.10
	MR	55	27.94	2.17	0.29		
4	780N	57	34.86	2.70	0.36	-0.60	0.55
	MR	55	35.16	2.54	0.34		
5	780N	55	29.17	2.68	0.36	-0.56	0.57
	MR	55	29.44	2.38	0.32		
6	780N	55	28.53	2.05	0.28	-0.60	0.55
	MR	55	28.76	1.89	0.25		
7	780N	56	30.35	2.28	0.30	-0.06	0.96
	MR	54	30.37	1.90	0.26		
8	780N	56	34.64	2.87	0.38	-2.57	0.01 *
	MR	54	35.95	2.47	0.34		
9	780N	55	91.43	5.94	0.80	-0.70	0.49
	MR	55	92.19	5.54	0.75		
10	780N	51	48.57	2.65	0.37	-0.42	0.67
	MR	55	48.77	2.34	0.31		

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No	Site	N	$\overline{X}$	SD	SE	T	*p*
11	780N	50	80.91	3.99	0.56	-2.61	0.01 *
	MR	50	82.83	3.30	0.47		
12	780N	51	62.27	3.28	0.46	-1.81	0.07
	MR	51	63.34	2.64	0.37		
13	780N	52	62.76	3.63	0.50	-2.22	0.03 *
	MR	50	64.22	2.98	0.42		
14	780N	32	30.13	1.83	0.32	-1.95	0.05 *
	MR	42	30.91	1.51	0.23		
15	780N	24	27.36	1.57	0.32	-0.35	0.73
	MR	34	27.53	2.12	0.36		
16	780N	39	44.61	2.94	0.47	-2.51	0.01 *
	MR	52	46.14	2.82	0.39		
17	780N	55	18.57	2.17	0.29	-1.36	0.18
	MR	54	19.08	1.77	0.24		
18a	780N	50	237.6	12.1	1.7	-3.69	0.000 *
	MR	55	246.8	13.5	1.8		
18b	780N	50	6.74	2.00	0.28	-1.98	0.05 *
	MR	55	7.55	2.17	0.29		
38	780N	56	81.85	5.56	0.74	-2.70	0.008*
	MR	55	84.89	6.28	0.85		
39	780N	56	127.4	5.74	0.77	0.22	0.83
	MR	55	127.1	6.20	0.84		
Height for left side only:							
	780N	114	168.8	0.05	0.00	-3.33	0.001*
	MR	110	170.9	0.05	0.00		

TABLE 5.8.4: RIGHT SIDE BY SITE.

No	Site	N	$\bar{X}$	SD	SE	T	*p*
1	780N	57	447.9	22.9	3.0	-2.28	0.02 *
	MR	55	457.3	20.5	2.8		
2	780N	56	445.7	22.0	2.9	-2.26	0.03 *
	MR	55	454.8	20.6	2.8		
3	780N	57	27.25	2.01	0.27	-2.49	0.01 *
	MR	55	28.20	2.01	0.27		
4	780N	57	34.22	2.68	0.35	-1.18	0.24
	MR	55	34.79	2.40	0.32		
5	780N	55	29.46	2.77	0.37	-0.92	0.36
	MR	55	29.91	2.38	0.32		
6	780N	55	28.35	1.82	0.25	-0.58	0.56
	MR	55	28.55	1.84	0.25		
7	780N	56	30.31	2.24	0.30	0.41	0.69
	MR	54	30.15	1.81	0.25		
8	780N	56	34.66	2.96	0.40	-2.55	0.01 *
	MR	54	36.02	2.67	0.36		
9	780N	55	91.63	5.92	0.80	-0.62	0.53
	MR	55	92.33	5.93	0.80		
10	780N	51	48.51	2.70	0.38	-0.96	0.34
	MR	55	48.99	2.49	0.34		

.....continued on the next page

No	Site	N	$\bar{X}$	SD	SE	T	*p*
11	780N	50	81.36	4.04	0.57	-2.21	0.03 *
	MR	50	82.99	3.27	0.46		
12	780N	51	62.92	3.52	0.49	-1.57	0.12
	MR	51	63.89	2.71	0.38		
13	780N	52	62.19	3.98	0.55	-1.66	0.10
	MR	50	63.35	3.01	0.43		
14	780N	32	30.29	2.08	0.37	-1.76	0.08
	MR	42	31.05	1.44	0.22		
15	780N	24	26.91	1.88	0.38	-1.16	0.25
	MR	35	27.55	2.30	0.39		
16	780N	39	46.25	3.11	0.50	-2.49	0.01 *
	MR	52	47.90	3.14	0.44		
17	780N	55	18.56	1.59	0.21	-1.20	0.23
	MR	54	18.93	1.61	0.22		
18a	780N	50	236.2	14.6	2.1	-3.37	0.001*
	MR	55	245.3	13.3	1.8		
18b	780N	50	6.90	2.03	0.29	-2.51	0.01 *
	MR	55	7.95	2.24	0.30		
38	780N	56	80.40	5.98	0.80	-2.58	0.011*
	MR	55	83.36	6.10	0.82		
39	780N	56	126.3	6.33	0.85	1.23	0.22
	MR	55	124.7	6.84	0.92		

TABLE 5.9

TWO SAMPLE t TESTS FOR HUMERAL X-RAY DIMENSIONS
FOR THE YA: WHOLE GROUP.

The measurements are given in the numerical order shown in figure 4.1.
KEY: N = number in sample; $\overline{X}$ = mean; SD = standard deviation; SE = standard error of mean; T = t value; p = level of significance;
Archaeological groups = 1; divers = 2.

TABLE 5.9.1: LEFT SIDE BY SITE.

No	Site	N	$\overline{X}$	SD	SE	T	*p*
8	1	46	24.55	1.86	0.27	-8.34	0.000*
	2	49	27.82	1.95	0.28		
9	1	46	15.75	1.82	0.27	-5.17	0.000*
	2	49	18.20	2.75	0.39		
10	1	46	8.81	1.50	0.22	-2.31	0.023*
	2	49	9.61	1.88	0.27		
11	1	46	278.8	53.7	7.9	-5.60	0.000*
	2	49	344.4	60.6	8.7		
12	1	46	35.85	5.53	0.81	0.72	0.47
	2	49	34.91	7.10	1.0		

TABLE 5.9.2: RIGHT SIDE BY SITE.

No	Site	N	$\overline{X}$	SD	SE	T	*p*
8	1	46	25.33	2.10	0.31	-6.69	0.000*
	2	49	28.20	2.08	0.30		
9	1	46	16.48	2.03	0.30	-5.12	0.000*
	2	49	18.90	2.57	0.37		
10	1	46	8.85	1.77	0.26	-1.26	0.21
	2	49	9.31	1.73	0.25		
11	1	46	291.0	63.7	9.4	-3.81	0.000*
	2	49	340.7	63.6	9.1		
12	1	46	35.30	6.72	0.99	1.49	0.14
	2	49	35.30	6.36	0.91		

TABLE 5.10

TWO SAMPLE t TESTS FOR HUMERAL X-RAY DIMENSIONS FOR THE MA FROM THE ARCHAEOLOGICAL SITES ONLY.

The measurements are given in the numerical order shown in figure 4.1.

KEY: N = number in sample; $\overline{X}$ = mean; SD = standard deviation; SE = standard error of mean; T = t value; p = level of significance.

TABLE 5.10: BOTH SIDES BY SITE.

No	Side	Site	N	$\overline{X}$	SD	SE	T	*p*
10	L	780N	32	8.32	1.20	0.21	-2.11	0.043*
		MR	20	9.19	1.57	0.35		
10	R	780N	32	8.09	1.19	0.21	-2.03	0.051*
		MR	20	8.99	1.75	0.39		
11	L	780N	32	268.5	35.2	6.2	-2.49	0.02 *
		MR	20	305.0	59.2	13.0		
11	R	780N	32	271.5	41.3	7.3	-2.03	0.052*
		MR	20	304.8	65.8	15.0		

TABLE 5.11

TWO SAMPLE t TESTS FOR FEMORAL X-RAY DIMENSIONS FOR THE YA: WHOLE GROUP.

The measurements are given in the numerical order shown in figure 4.2.
KEY: N = number in sample; $\overline{X}$ = mean; SD = standard deviation; SE = standard error of mean; T = t value; p = level of significance.
Archaeological groups = 1; divers = 2.

TABLE 5.11: BOTH SIDES BY SITE.

No	Side	Site	N	$\overline{X}$	SD	SE	T	*p*
33	L	1	63	29.79	2.41	0.30	-2.79	0.006*
		2	50	31.14	2.66	0.38		
33	R	1	63	29.70	2.42	0.30	-3.32	0.001*
		2	50	31.32	2.68	0.38		
34	L	1	63	13.57	1.82	0.23	-4.36	0.000*
		2	50	15.20	2.10	0.38		
34	R	1	63	13.47	1.73	0.22	-4.61	0.000*
		2	50	15.24	2.24	0.32		
36	R	1	63	552.0	101.0	13.0	-1.91	0.05 *
		2	50	589.0	103.0	15.0		
37	L	1	63	54.46	4.99	0.63	3.11	0.002*
		2	50	51.35	5.51	0.78		
37	R	1	63	54.60	4.94	0.62	3.32	0.001*
		2	50	51.40	5.21	0.74		

TABLE 5.12

TWO SAMPLE t TESTS FOR FEMORAL X-RAY DIMENSIONS FOR THE YA FROM THE ARCHAEOLOGICAL SITES ONLY.

The measurements are given in the numerical order shown in figure 4.2.
KEY: N = number in sample; $\overline{X}$ = mean; SD = standard deviation; SE = standard error of mean; T = t value; p = level of significance.

TABLE 5.12: BOTH SIDES BY SITE.

No	Side	Site	N	$\overline{X}$	SD	SE	T	*p*
33	L	78ON	31	29.15	2.53	0.45	-2.11	0.039*
		MR	32	30.41	2.16	0.38		
33	R	78ON	31	29.07	2.50	0.45	-2.11	0.039*
		MR	32	30.32	2.20	0.39		
34	R	78ON	31	12.97	1.82	0.33	-2.32	0.024*
		MR	32	13.95	1.51	0.27		

5.5 THE WILCOXON/MANN-WHITNEY U TEST.

This confidence interval and test was applied to the data from the scoring of the depth of lesions occurring at specific areas of muscle insertion on the humerus, as discussed in chapter 4. Originally, the intention had been to apply this test to the data from each age group and archaeological site, separately. The results of the test on the whole group by side, however, showed no significant differences ($W = 9737.5$ and $p = 0.780$). Further, there were few lesions occurring at any sites. Therefore, it was decided to abandon any further analysis of these lesions. The Wilcoxon test was also applied to the scoring of the muscle insertions on the humerus and the femur, considering both sides together. There were no significant differences when the scores were examined by this test, and no further analysis of these scores was attempted.

5.6 ANALYSIS OF VARIANCE.

Although the Wilcoxon test had shown no significant differences in the muscle insertion scores between the two sides, Analysis of Variance proved to be more useful. In this test, the muscle scores were compared with the cortical area and the percentage of cortex present at the same position as that used for the muscle evaluation, for each pair of bones. The significant results are shown in Tables 5.13 - 5.15. There were no significant differences in any of the results for this test in the following:

Humeral X-ray results and muscle scores for the MA from both archaeological sites.

Femoral X-ray results and muscle scores for the YA from both archaeological sites;
Femoral X-ray results and muscle scores for the MA from the *Mary Rose*.

It should be noted that, in the tables, some non-significant (NS) results have also been included for comparative purposes. The results will be discussed in chapter 6.

TABLE 5.13: ANALYSIS OF VARIANCE FOR X-RAYS AND MUSCLE SCORES: YA HUMERI FROM THE MR.

5.13.1 Cortical area : latissimus dorsi on the left.

5.13.2 Cortical area : latissimus dorsi on the right.

5.13.3 Cortical area : teres major on the left (NS).

5.13.4 % Cortex : deltoid on the left.

5.13.1

```
ANALYSIS OF VARIANCE ON C40
SOURCE     DF        SS         MS         F        p
C45         3     19382       6461      4.94    0.021
ERROR      11     14375       1307
TOTAL      14     33757
                                    INDIVIDUAL 95 PCT CI'S FOR MEAN
                                    BASED ON POOLED STDEV
LEVEL       N      MEAN      STDEV  --------+---------+---------+--------
    1       4    251.00      35.87  (-------*-------)
    2       4    263.50      38.97     (-------*-------)
    3       3    338.33      50.06                  (---------*--------)
    4       4    319.50      17.75               (-------*-------)
                                    --------+---------+---------+--------
POOLED STDEV =    36.15                   250       300       350
```

5.13.2

```
ANALYSIS OF VARIANCE ON C40
SOURCE     DF        SS         MS         F        p
C45         3     32065      10688      3.61    0.049
ERROR      11     32564       2960
TOTAL      14     64629
                                    INDIVIDUAL 95 PCT CI'S FOR MEAN
                                    BASED ON POOLED STDEV
LEVEL       N      MEAN      STDEV  -------+---------+---------+---------
    1       3    255.67      54.79  (--------*--------)
    2       4    280.50      68.80       (------*-------)
    3       5    345.00      52.87              (------*------)
    4       3    379.00      24.25                  (-------*--------)
                                    -------+---------+---------+---------
POOLED STDEV =    54.41                  240       320       400
```

5.13.3

```
ANALYSIS OF VARIANCE ON C40
SOURCE     DF        SS         MS         F        p
C45         4      8337       2084      0.82    0.541
ERROR      10     25420       2542
TOTAL      14     33757
                                    INDIVIDUAL 95 PCT CI'S FOR MEAN
                                    BASED ON POOLED STDEV
LEVEL       N      MEAN      STDEV  -+---------+---------+---------+-----
    0       1    324.00       0.00         (-------------*-------------)
    1       2    236.00      53.74   (---------*--------)
    2       5    286.40      32.66             (-----*-----)
    3       4    301.00      76.35              (------*------)
    4       3    306.33      19.73             (-------*-------)
                                    -+---------+---------+---------+-----
POOLED STDEV =    50.42            160       240       320       400
```

5.13.4

```
ANALYSIS OF VARIANCE ON C40
SOURCE     DF        SS         MS         F        p
C45         2     179.2       89.6      3.90    0 050
ERROR      12     275.7       23.0
TOTAL      14     454.9
                                    INDIVIDUAL 95 PCT CI'S FOR MEAN
                                    BASED ON POOLED STDEV
LEVEL       N      MEAN      STDEV  -------+---------+---------+---------
    1       1    45.900      0.000            (-----------*------------)
    2       5    31.840      6.026   (-----*-----)
    3       9    36.189      4 037         (---*----)
                                    -------+---------+---------+---------
POOLED STDEV =    4.793                  32.0      40.0      48.0
MTB > nopa
```

TABLE 5.14: ANALYSIS OF VARIANCE FOR X-RAYS AND MUSCLE SCORES: YA HUMERI FROM 780N.

5.14.1 Cortical area : pectoralis major on the left.

5.14.2 Cortical area : pectoralis major on the right (NS).

5.14.3 Cortical area : latissimus dorsi on the left (NS).

5.14.4 Cortical area : latissimus dorsi on the right.

5.14.1

```
ANALYSIS OF VARIANCE ON C40
SOURCE       DF          SS          MS         F         P
C45           4       28330        7082      2.81     0.047
ERROR        25       62998        2520
TOTAL        29       91328
                                           INDIVIDUAL 95 PCT CI'S FOR MEAN
                                           BASED ON POOLED STDEV
LEVEL         N        MEAN       STDEV   -------+---------+---------+---------
    0         3      200.67       59.28   (---------*---------)
    1         8      253.50       44.10               (-----*-----)
    2         7      292.71       45.88                     (-----*-----)
    3         9      298.56       33.44                       (-----*-----)
    4         3      292.00      101.93                  (---------*---------)
                                          -------+---------+---------+---------
POOLED STDEV =        50.20                    180       240       300
```

5.14.2

```
ANALYSIS OF VARIANCE ON C40
SOURCE       DF          SS          MS         F         P
C45           4       23827        5957      1.90     0.142
ERROR        25       78536        3141
TOTAL        29      102363
                                           INDIVIDUAL 95 PCT CI'S FOR MEAN
                                           BASED ON POOLED STDEV
LEVEL         N        MEAN       STDEV   ----+---------+---------+---------+--
    0         3      223.33       46.93   (----------*----------)
    1         9      256.22       48.09             (------*-----)
    2         5      286.80       67.10                (--------*-------)
    3        10      304.10       57.72                      (-----*-----)
    4         3      312.00       61.80                 (----------*----------)
                                          ----+---------+---------+---------+--
POOLED STDEV =        56.05                  180       240       300       360
```

5.14.3

```
ANALYSIS OF VARIANCE ON C40
SOURCE       DF          SS          MS         F         P
C45           4       16238        4060      1.35     0.279
ERROR        25       75090        3004
TOTAL        29       91328
                                           INDIVIDUAL 95 PCT CI'S FOR MEAN
                                           BASED ON POOLED STDEV
LEVEL         N        MEAN       STDEV   -+---------+---------+---------+-----
    0         5      228.40       66.70    (-------*-------)
    1         9      269.11       53.35             (-----*-----)
    2         7      292.43       63.71                (------*-------)
    3         7      289.57       37.36               (------*-------)
    4         2      302.00       42.43           (------------*------------)
                                          -+---------+---------+---------+-----
POOLED STDEV =        54.80              180       240       300       360
```

5.14.4

```
ANALYSIS OF VARIANCE ON C40
SOURCE       DF          SS          MS         F         P
C45           4       36299        9075      3.43     0.023
ERROR        25       66064        2643
TOTAL        29      102363
                                           INDIVIDUAL 95 PCT CI'S FOR MEAN
                                           BASED ON POOLED STDEV
LEVEL         N        MEAN       STDEV   --------+---------+---------+--------
    0         4      210.75       45.84    (------*-------)
    1        12      281.00       54.99                 (---*----)
    2         6      267.00       41.98             (-----*-----)
    3         5      307.60       64.01                  (------*------)
    4         3      344.00       25.51                      (--------*--------)
                                          --------+---------+---------+--------
POOLED STDEV =        51.41                     210       280       350
```

TABLE 5.15: ANALYSIS OF VARIANCE FOR X-RAYS AND MUSCLE SCORES: MA FEMORA FROM 780N.

5.15.1 Cortical area : gluteus maximus on the left.

5.15.2 Cortical area : adductors/vasti on the left.

5.15.1

```
ANALYSIS OF VARIANCE ON C55
SOURCE       DF        SS         MS         F        P
C56           3    112935      37645      4.86    0.011
ERROR        19    147303       7753
TOTAL         22    260238
                                        INDIVIDUAL 95 PCT CI'S FOR MEAN
                                        BASED ON POOLED STDEV
LEVEL         N      MEAN      STDEV   --+---------+---------+---------+----
    0         1    317.00       0.00   (----------*----------)
    2         3    555.67     128.47                    (------*-----)
    3         9    645.33      69.53                            (---*---)
    4        10    560.70      91.66                       (---*---)
                                       --+---------+---------+---------+----
POOLED STDEV =      88.05             160       320       480       640
```

5.15.2

```
ANALYSIS OF VARIANCE ON C55
SOURCE       DF        SS         MS         F        P
C56           4    113206      28302      3.11    0.041
ERROR        18    163888       9105
TOTAL        22    277094
                                        INDIVIDUAL 95 PCT CI'S FOR MEAN
                                        BASED ON POOLED STDEV
LEVEL         N      MEAN      STDEV   ---+---------+---------+---------+---
    0         1    317.00       0.00   (-----------*-----------)
    1         2    463.00      22.63               (--------*--------)
    2         9    582.78      83.38                           (---*----)
    3         6    620.17     120.65                             (----*----)
    4         5    617.40      93.50                            (-----*----)
                                       ---+---------+---------+---------+---
POOLED STDEV =      95.42              160       320       480       640
```

5.7 THE *CHI*-SQUARE TEST.

The *chi*-square test was applied to the presence/absence of femoral discontinuous morphological traits. The results are presented in table 5.16 and will be discussed in chapter 6. Some non-significant results are included for comparison.

TABLE 5.16

CHI SQUARE FOR FEMORAL DISCONTINUOUS TRAITS.

The traits are given in the numerical order shown in figure 4.2.

TABLE 5.16.1: LEFT SIDE BY AGE.

No	Age	Absent	Present	X^2	*p*
40	YA	44	20	10.51	0.001*
	MA	45	3		
41	YA	34	30	6.78	0.009*
	MA	37	11		
42	YA	47	17	4.32	0.037*
	MA	42	5		
44	YA	52	12	4.26	0.039*
	MA	30	17		
45	YA	46	17	6.68	0.01 *
	MA	23	24		

TABLE 5.16.2: RIGHT SIDE BY AGE.

No	Age	Absent	Present	X^2	*p*
40	YA	45	19	4.67	0.031*
	MA	42	6		
41	YA	38	26	3.89	0.048*
	MA	37	11		
42	YA	49	15	5.80	0.016*
	MA	44	3		
44	YA	52	12	5.25	0.022*
	MA	29	18		
45	YA	45	18	5.77	0.016*
	MA	23	24		

TABLE 5.16.3: BOTH SIDES BY SITE.

No	Site	L	R	Absent	Present	X^2	*p*
40	78ON	x		48	9	1.60	0.205
	MR	x		41	14		
40	78ON		x	49	8	4.60	0.032*
	MR		x	38	17		
41	78ON	x		35	22	0.20	0.656
	MR	x		36	19		
41	78ON		x	38	19	0.005	0.944
	MR		x	37	18		

Note: x signifies the trait present by side.

5.8 DESCRIPTIVE STATISTICS.

Summary descriptive statistics will be found in the Appendix. These describe the distribution of all measurements, both long bone and radiographic, for both pairs of bones. They are tabulated in the key to the tables.

CHAPTER 6. DISCUSSION

AND

CONCLUSIONS.

6.1 INTRODUCTION.

Humeral maximum length asymmetry has been shown to have a genetic basis. In his 1937 paper Schultz discusses his earlier work (1926) in which he measured 100 white fetuses. The analysis of these measurements demonstrated the right humerus to be longer than the left in 52% of the cases, the left to be longer than the right in 21% of the cases and for there to be symmetry in the remaining 27% of the cases. As Schultz says : "Even in early development, therefore, human asymmetries of the upper extremities are more frequently in favor of the right than the left side" (1937, p308). Pande and Singh (1971) removed and weighed muscle and bone from the upper limbs of 10 fetuses. Their work demonstrated that the total muscle and bone weight was significantly greater statistically on the right side in 9 of the 10 fetuses ($p < 0.001$). Humeral maximum length asymmetry should, therefore, be regarded as an expression of congenital asymmetry. However, asymmetries that are not congenital in origin also occur in both the humerus and femur (Lowrance and Latimer, 1957; Latimer and Lowrance, 1965). Various workers have demonstrated the existence of a "crossed symmetry", where both the right humerus and the left femur are longer than the opposing side (Arnold, 1844; Lowrance and Latimer, 1957; Latimer and Lowrance, 1965). Others have demonstrated that asymmetry of the humerus is more marked than that of the femur (Schultz, 1937; Jolicoeur, 1963).

It is clear that measurement differences are likely to be small. Therefore, measurements of single skeletons, or of small samples, will not provide accurate information. It is for this reason that sample sizes of at least 30 individuals are required. It should be noted that some investigations have used small samples, (for example, Borgonini Tarli and Repetto, 1986; Dutour, 1986; Formicola, 1986; Constandse-Westermann and Newell, 1989), and in some cases no sample size at all was reported (Tainter, 1980; Molleson, 1989). Clearly, the smaller the measurement differences, the larger the number of readings necessary to obtain reliable mean values. However, the mean values *per se* are still insufficient because the spread of readings about the mean, (the standard deviation), may overlap between two samples which are being compared. Thus, statistical analysis is essential in order to try to reveal differences. The interpretation of the statistical results can be made less subjective by defining an acceptable level of confidence. In all the present analyses, a confidence level of $p \leqslant 0.05$ has been adopted. Of course, the rigorous application of this level of significance may exclude some results that are clearly different. What does such statistical significance mean in archaeology?

Archaeological samples are both non-random and incomplete. They are derived from populations which are themselves sampled. Therefore, any research which uses archaeological remains is working with samples of sampled populations. In the analysis of such research, statistics are used to try and reconstruct the sampled, but not the general, population. The problem presented by the statistical analysis is that the chosen level of significance alone may become the dominating factor in the discussion of the results. As the level of significance is an arbitrary cut-off point chosen to aid in the assessment of the results, it may not include apparent differences which will be present and also worthy of consideration. Therefore, when such apparent differences occur in the present results, they also will be included in the discussion.

Skeletal asymmetry and activity were discussed in chapter 2. The sex and age of individuals in comparative samples are important factors in the occurrance of skeletal asymmetry (Ruff and Jones, 1981, Schell *et al.*, 1985). However, in much of the literature pertaining to activity-related change, skeletal asymmetry, sex and age have all been ignored, either separately or in combination (see, for example, Ubelaker, 1979; Dutour,1986; Borgonini Tarli and Repetto, 1986; Bridges, 1989; Molleson, 1989; Constandse-Westermann and Newell, 1989). In the present study only males were compared; they were divided into two broad age cohorts.

All measurements have been subjected to a series of statistical tests, as discussed and presented in chapters 4 and 5. Correlation coefficients have also been calculated for the measurements from each pair of bones. The resulting values have then been tested for significance using critical values of Pearson's r for a two-tailed test. The results of all tests will be discussed for each bone pair separately, beginning with the humerus.

6.2. THE HUMERUS.

6.2.1. The Correlations.

In order to correlate the eleven humeral measurements, all the samples were first divided into left and right sides. The measurements were then correlated separately for the whole sample and for the two archaeological samples. The results are as follows:

6.2.1.1 The whole sample consisted of 100 pairs of humeri. As with all the tests, the level of significance had to be at least 0.05. For a sample of this size and at this level of significance, the critical value of Pearson's *r* had to be equal to or more than 0.195.

The measurements which showed no significance when correlated were those of the midshaft compared with those of the tubercles. This was true for both the left and right sides and for the midshaft maximum and minimum when compared with the lesser tubercle dimensions. Torsion was not significantly correlated with any other measurement on the right side and only with maximum length, proximal breadth, diameter of the head and the greater tubercle on the left side. (see Appendix II a).

Highly significantly correlated measurements on both sides were those which could probably have been anticipated. They included the diameter of the head with the proximal breadth and the midshaft measurements with the circumference (Appendix II a). All showed a significance of >0.001. Other highly correlated measurements were the maximum length with proximal breadth, distal breadth and the midshaft measurements; the midshaft measurements with both proximal and distal breadth. Proximal breadth was highly correlated with the distal breadth and the head with the greater tubercle. All these measurements were significant at the $p = 0.001$ level or better.

6.2.1.2 <u>The Norwich sample</u> consisted of 64 pairs of humeri. The critical value of Pearson's *r* for this sample size must be equal to or greater than 0.250.

The measurements which showed the majority of non-significant correlations in the Norwich sample were those involving the lesser tubercle and those involving torsion. The results were similar to the ones for the whole sample. This was not unexpected as the Norwich sample comprised almost 2/3rds of the whole sample. Although the results were similar, however, more measurements showed low non-significant correlations in the Norwich sample than in the whole sample. On the left side, the dimensions of the lesser tubercle had low correlations with the head, the proximal and distal breadths, the maximum length and with each other. This is in addition to the low correlations of the dimensions of this tubercle with those of the midshaft (see Appendix II b). Torsion was only significantly correlated with maximum length, distal breadth and the greater tubercle on this side. On the right side, the horizontal dimension of the lesser tubercle showed the same low correlation with the midshaft measurements as on the left, and also with the greater tubercle. Further, the depth of this tubercle showed low correlations with all measurements except its own horizontal dimension (Appendix II b). On this side, torsion was not significantly correlated with any other measurement. As with the whole sample, the measurements which showed the highest correlations were those of the proximal, distal and midshaft areas and the maximum length.

6.2.1.3 <u>The *Mary Rose* sample</u> consisted of 36 pairs of humeri. The critical value of Pearson's *r* for this sample size must be equal to or greater than 0.325.

In the *Mary Rose* sample, torsion demonstrated no significant relationship with any other measurement on either side. As with the other two samples, the non-significant correlations occurred with the dimensions of the lesser tubercle compared with other measurements on both sides. The results were similar to those from the Norwich sample (see Appendix II c). There were, however, fewer measurements showing high correlations in this sample than in the other two. Thus, although the same <u>trends</u> of high correlations in the proximal, distal and midshaft measurements occurred in the sample from the *Mary Rose*, fewer of them were significantly correlated with each other.

In summary for all the groups, while there were highly significant correlations between the maximum length of the humerus and measurements of the proximal and distal breadths and of the midshaft, a specific portion of the bone (namely the lesser tubercle) demonstrated a low correlation with these same areas. Most dramatically, torsion of the humerus demonstrated either no relationship or a very low correlation with all other measurements.

6.2.2 The Sub-Sample for Site.

The sub-sample constructed in order to compare the archaeologcial sites consisted of 36 paired humeri from the *Mary Rose* and 64 paired humeri from Norwich. Initially, the frequency of asymmetries was tested for each site by application of the sign test (see table 5.1). The results demonstrated six humeral asymmetries from Norwich and one from the *Mary Rose*. Maximum length showed a right-sided dominance in the sample from Norwich. While this asymmetry is congenital in origin, it is not present in the sample from the *Mary Rose*. Prives (1960), however, states : "Physical work favors the growth of bones in length". Clearly, it is possible that congenital asymmetry in the maximum length of the humerus may be enhanced by preferential use of the right arm. If this is so, one implication is that, while the group from Norwich follows the 'normal' pattern of asymmetry, that from the *Mary Rose* does not. The latter may have been using their arms more equally over time than the former, thus masking the congenital asymmetry by activity.

The group of midshaft dimensions (maximum and minimum diameters and circumference) demonstrated highly significant differences between the two samples; the Norwich men showed a right-sided dominance in all three measurements, while the *Mary Rose* men did not. However, the 'midshaft' should be considered as a metrically convenient, rather than a functionally significant, point. 'Functionally significant' points are those where changes in the dimensions of the bone can be related to aspects of its function. They would include, for example, areas of muscle insertion. The midpoint of the humeral shaft lies at equal distance from the proximal and distal epiphyses, and is used merely as a convenient measuring point. It is, therefore, difficult to explain the marked right-sided dominance in the analysis of the measurements taken there. They are not, unlike the maximum length, expressing congenital asymmetry. There is another possibility, however.

In their study of asymmetry in 135 white adolescents, Schell *et al.* (1985) measured various dimensions of the upper and lower limbs. These included the upper arm circumference which "was taken with a flexible tape at the mid-point between acromiale and the lowest border of the bent elbow" (p318). This point corresponds with the midshaft point on the dry humerus. The results demonstrated a significant asymmetry in favour of the right side ($p < 0.001$) in the 116 right handed subjects. The authors suggested that handedness can contribute to the development of asymmetries in the upper arm during adolescence. The preferred side is used more, thus developing the musculature on this side, hence resulting in the larger upper arm circumference. The upper arm measurement taken on the living would have included the deltoid, which inserts just above midshaft on the deltoid crest. The midshaft measuring point on most dry bone samples is at the distal end of the crest and includes part of the muscle insertion. Perhaps the increased midshaft dimensions on the right side in the Norwich sample also reflect handedness. The lack of midshaft asymmetry in the *Mary Rose* sample may again reflect a more 'even-handedness'. Clearly, these results suggest that the midshaft measuring position may, after all, have functional significance.

The horizontal dimension of the greater tubercle showed a significant increase on the right side. This asymmetry was the only one to occur in both the archaeological samples. The measurement of this tubercle was specifically devised for the present study in order to evaluate areas of insertion of muscles which have particular functions. The muscles which form the rotator cuff insert on this tubercle (see chapter 3); they work with deltoid to abduct and rotate the shoulder and arm in a range of movements. The tubercle with its areas of muscle insertion has not been specifically studied and discussed before. However, there have been a number of publications on the effects of repeated use of the arm and shoulder in various sports which have included discussion of these areas.

King *et al.* (1969) analysed the pitching arm of 50 professional baseball pitchers. They demonstrated that a considerable degree of muscle hypertrophy develops in that part of the pitching arm which "----generally extends proximally to the shoulder" (p117). The asymmetric involvement of the entire shoulder girdle is illustrated (Fig. 1 A). Mann and Littke (1989) investigated shoulder injuries in 21 'elite' archers. Frequent asymmetries were found in the shoulder girdle. In both these examples, hypertrophy of the shoulder muscles was related to asymmetric loading during repeated activity. The asymmetry of the greater tubercle demonstrated here may also be related to use. The possibility of increased activity and larger muscles affecting the size of bones was discussed in chapter 3. As was the case with the midshaft asymmetries, therefore, there is arguably a connection between the preferential use of the right shoulder girdle and the right-sided dominance of the greater tubercle, in both the archaeological samples.

The final measurement which demonstrated a right sided dominance in the Norwich sample was the proximal breadth. Thus, the sample from Norwich were far more asymmetric than the sample from the *Mary Rose*. How can these asymmetries be explained? Are they related to a) body size or b) to differences in activity?

Humerus length, (as a measure of size), has been correlated with the asymmetries discussed above. This has been done for the whole sample (which, of course, is biased by the size of the Norwich group) and for each of the archaeological subsamples. The results are presented in table 6.1 and will be discussed.

TABLE 6.1

CORRELATIONS OF BODY SIZE AND ASYMMETRY: THE HUMERUS.

TABLE 6.1.1: THE WHOLE SAMPLE.

Humeral maximum length is correlated with:
Diameter of the head = 0.614;
Midshaft maximum = 0.387;
Midshaft minimum = 0.448;
Circumference = 0.457;
Greater tubercle = 0.356.

TABLE 6.1.2: THE NORWICH SAMPLE.

Humeral maximum length is correlated with:
Proximal breadth = 0.661;
Midshaft maximum = 0.381;
Midshaft minimum = 0.399;
Circumference = 0.445;
Greater tubercle = 0.374.

TABLE 6.1.3: THE *MARY ROSE* SAMPLE.

Humeral maximum length is correlated with:
Greater tubercle = 0.347.

Using values of Pearson's *r* for a one-tailed test and the relevant sample sizes, all the results in table 6.1 are significant at the $p = 0.025$ level or better. It can be seen from the table, therefore, that there is a weak but significant relationship between size and asymmetry in the humerus, i.e., bigger men do tend to be more asymmetric. Thus, asymmetry would appear to be related in some degree to body size. However, for each of the coefficients expressed in the table, less than 50% of the relationship between the measurements can be explained by size only (this result is derived by squaring the correlation coefficient values in table 6.1). Relationships not explained by size alone must be due to other factors. Therefore, function in the form of handedness and/or activity is probably involved. How do the results so far discussed compare with those from the t tests?

The t tests were applied to the two archaeological samples by comparing each side from the two sites. In other words, the left humeri from the *Mary Rose* were compared with the left humeri from Norwich and the right bones were similarly compared. The results of the t tests (table 5.7) provided two measurements only which showed statistically significant differences between the sites: the diameter of the head ($p = 0.04$) and the horizontal dimension of the greater tubercle ($p = 0.01$). The dimensions of the sample from the *Mary Rose* were larger than those from the Norwich sample. Indeed, the means of the measurements from the *Mary Rose* sample exceeded the means of those from Norwich in all dimensions with the exception of the depth of the lesser tubercle and torsion on the left side, and midshaft maximum and circumference on the right side (table 5.7). The differences between these means were very small (0.37% and 0.69% for the first two and

1.06% and 0.71% for the second two, respectively). The two significantly different dimensions between the sites, however, were larger on the left side. Clearly, most dimensions of the sample from the *Mary Rose* were larger than those of the sample from Norwich, and significantly different for two values, both of which were on the left side. These results are in direct contrast with those from the sign tests between the sites, which tested the asymmetries. How can they be explained?

In a previous study, Stirland (1984) found a high frequency (13.5%) of *os acromiale* (non-fusion of the final element of the acromion process) in the sample from the *Mary Rose*. Re-examination of the sample has increased the frequency to >14%. There is a predominance of this condition on the left side. An association was made between *os acromiale* and the archers on the ship. Recent discussions (Hardy, 1991) have indicated that most of the long bows from the ship had a draw weight of >125 lbs. (The "draw weight" or "bow weight" is measured as the force required to pull a bow string to the fully drawn position. Several of the bows from the *Mary Rose* were tested to destruction at Imperial College, University of London and their draw weights were determined). In their study of 'elite' archers, Mann and Littke (1989) stated that: "During the course of an international event, a male archer will pull a bow 75 times a day for four days. This equals approximately 3400 lb (1546 kg) pulled in a single day, and represents an enormous strain on the bony, ligamentous and muscular structures of the shoulder girdle" (p85). The authors found evidence for frequent asymmetry with shoulder girdle hypertrophy of the bow arm (the arm that holds the bow, p88). Hardy has stated (*ibid.*) that the discomfort and stress involved in drawing a long bow of 100 lbs is felt mainly in the cervical spine, the left shoulder and the upper arm. This is a function of the technique employed in shooting the bow (Stirland, 1984, p328). It has also been stated that: "The forces exerted and the stresses involved in this archery were much greater than anything encountered by the majority of modern archers" (Stirland, *ibid.*).

The sample from the *Mary Rose* demonstrated statistically significant differences in two measurements of the left shoulder. From the amount and type of equipment excavated, there are known to have been archers on board the ship. It has been suggested that these may have included a group of 'special' archers (Rule, 1991). In this sub-sample the changes are predominantly on the left. It is difficult to explain this difference other than by a pattern of activity. Long-term use of a heavy medieval long bow has been demonstrated as affecting the bow or non-drawing arm, usually the left arm. Therefore, it is a reasonable inference that the skeletal sample from the ship contains a high frequency of archers. However, the generally larger dimensions of the sample from the *Mary Rose* when compared with the sample from Norwich is not necessarily explained by different patterns of activity. Other environmental explanations may be relevant and will be discussed in the section on the femur.

Given the distribution of the asymmetries between the sites, the analysis of the humeral indices for the site sub-sample produced some unsurprising results. There were no significant side differences in the sample from the *Mary Rose*. The midshaft and the robusticity indices showed an equal distribution between the sides (table 5.5.2). Both the tubercle indices had the same level of significance ($p < 10$), although the tubercle index was larger on the left side and the lesser tubercle index was larger on the right side. The robusticity index in the Norwich sample demonstrated that the right side was significantly larger than the left ($p < 0.0005$), whereas in the *Mary Rose* sample, both sides had equal dominance. In the latter case the arms were equally robust indicating their equal size and probably their equal use. The similar, equal distribution of the midshaft index between the sides in this sample supports the argument, as does the lack of asymmetry demonstrated by the sign tests (and assuming that asymmetry has some functional component). Note that many of the activities undertaken on board a late medieval fighting ship, such as the raising and lowering of sails or operation of the gun carriages, would involve the equal use of both arms. What of the dominance of the right side in the robusticity index in the Norwich sample, however?

Hrdlička (1932) produced a similar index to that of robusticity ("index of strength") which he evaluated by sex and racial group, but not by side. Although not comparable, Hrdlicka's work demonstrated an increase in "strength" (robusticity) in groups of males engaged in heavy physical work. The significant dominance of the right side in this index in the Norwich results suggests a preferential use of the right arm. Clearly, the least circumference of the humerus demonstrated a significant side difference in favour of the right when standardised for this group (left side divided by right side, see chapter 5) and when analysed as an index of robusticity (divided by the maximum length, see chapter 3). It is difficult to explain this in any way other than by preferential use.

The X-ray data compared between the archaeological sites and discussed here are for the Mature Adults only. The results for the Young Adults from the archaeological sites showed no significant differences in any dimensions. Table 5.3.2 illustrates the results of the sign test for the Mature Adults. Since they are compared for the two archaeological sites alone, they have been included in this section. As was the case for the Young Adults, total subperiosteal diameter ($p < 0.001$) and medullary cavity width ($p < 0.005$) demonstrate significant differences between the sides for this group. In each case, the right side is dominant. Therefore, the same pattern of dominance is seen in the same two measurements for both the age sub-samples. Ruff and Jones (1981) found a decrease in cortical area asymmetry with age. Although this value is not significantly asymmetric in the Young Adult sample ($p < 0.3$), the asymmetry detected is in favour of the right side. In the Mature Adult sample cortical area is more symmetric (left dominance = 27; right dominance = 25). These results therefore also suggest a possible decrease in asymmetry with age.

Other dimensions demonstrate significant differences when the Mature Adults from the two archaeological sites are compared (table 5.10). The total cortex and the cortical area are larger on both sides for the *Mary Rose* sample than they are for the Norwich sample. The differences are large. There is a 9.47% increase in total cortex on the left and a 10% increase in total cortex on the right in the *Mary Rose* sample, and the cortical area is 11.97% greater on the left and 10.9% greater on the right than in the Norwich group. The relationship of activity and an increase in cortical bone will be discussed in the following section on the age groups. These results show an increase in the amount of cortical bone in the *Mary Rose* sample in both humeri for the Mature Adults. Tanner (1964) makes two points. Firstly, he suggests that successful athletes may be born with the appropriate physique and attracted to a suitable sport to develop it. Secondly, the exercise involved in a sport may thicken the cortex through the pull of muscles on the periosteum. The increased cortex of the men of the *Mary Rose* may have a similar explanation. The crew of King Henry VIII's flagship could have been chosen initially for their physique; the exercise of their occupations on board the ship could have further developed this physique. Is it possible that the 'older' individuals represented by the Mature Adult sample were involved in these occupations for long enough to affect the amount of cortex in their humeri?

Only the Young Adults from the archaeological sites showed significant differences in the ranked muscle scores and the amount of cortex present in the humerus (see tables 5.13 and 5.14). Significant results were obtained for the following:

For the *Mary Rose*:

Cortical area/ latissimus dorsi $p = 0.02$ left; 0.05 right

% cortex/ deltoid $p = 0.05$ left

For Norwich:

Cortical area/ pectoralis major $p = 0.05$ left

Cortical area/ latissimus dorsi $p = 0.02$ right

In the case of the group from the *Mary Rose* increased cortical area occurred with a larger muscle score for latissimus dorsi on both sides (table 5.13). Latissimus dorsi is a medial rotator, working with other muscles to adduct and move the arm across the chest (see chapter 3). In this sample, its even distribution suggests an equal development of the muscle in both arms. The case of the percent cortex and deltoid is rather different. Here, the highest percentage occurred with the lowest muscle score, a result which is difficult to explain. In the group from Norwich the largest cortical area was matched with pectoralis major on the left and with latissimus dorsi on the right. An equal development of both arms is again implied. Caution must be exercised in the interpretation of these results. Like other muscles, pectoralis major and latissimus dorsi do not work in isolation. They are instrumental together and with other muscles, particularly deltoid, in a whole range of movements. Any subjective scoring of individual muscle insertions obscures their patterns of co-operative activity. Therefore, such individual scoring should not be used to propose specific activities.

6.2.3. The Sub-Sample for Age.

The sub-sample constructed for age consisted of 47 pairs of Young Adult and 53 pairs of Mature Adult humeri (see chapter 3). It was not practical to sub-divide these groups into age sets for both archaeological sites, since this would have yielded from the *Mary Rose* a Young Adult group of only 16 individuals. These samples were too small for accurate analysis (see the Introduction to this chapter). Accordingly, the two age sets were compared separately for each side, as discussed in chapter 4; site specific age-related change was not considered. An exception was made, however, for comparison of the X-ray measurements between the archaeological sites. Here there were 32 Mature Adults from Norwich and 20 Mature Adults from the *Mary Rose*.

Only two humeral measurements demonstrated significant levels of asymmetry when examined by age groups. These were the maximum midshaft diameter on the left (p = 0.04) and the horizontal dimension of the greater tubercle on both sides (left : $p = 0.01$; right : $p = 0.05$) (table 5.7.1). In both dimensions, the Mature Adults were larger than the Young Adults. The Mature Adults were larger on both sides in all dimensions except the midshaft minimum, where the results were almost identical for both sides. How do these results compare with those from other work?

Pfeiffer (1980) found significant increases in the lateral dimensions of the humerus with age in a large ossuary sample. Similar age divisions to those in the present research were adopted. Comparisons of eight dimensions were made between the "young" and the "full" adults. Apart from the maximum length on the left side, (where the young adults were larger), an increase in size on both sides occurred with age. These results agree with those from the present study. However, the statistically significant results from Pfeiffer's work exhibit an increase on the right side with age in six of the eight chosen dimensions. There are two problems associated with this work. Although the ossuary was dated "from approximately 1600 AD", no *terminus ante quem* was given and there was no information concerning the stratification of the site or when burials were interred. Therefore, other unknown factors involved in the structure of the sample could have a bearing on the results. For example, periods of starvation or disease would disrupt the growth of younger individuals thus resulting in a change in the growth curve (Harrison *et al.,* 1988, p354). Such a disruption could affect other dimensions. In a cross-sectional study, where each 'individual' is only measured once and their temporal relationship to the other 'individuals' in the sample is unknown, there are problems in comparing the results. Of course, these are common problems in archaeological samples, where the data is usually cross-sectional in nature. To some degree, the same criticism can be levelled at the present research. This is modified, however, by the inclusion of the *Mary Rose* sample, since the death of the whole group was simultaneous. The other criticism which can be made of Pfeiffer's work is that no attempt was made to sex the measured humeri. Undoubtedly, her sample consisted of both male and female unpaired bones. Other work has demonstrated the importance of both age <u>and</u> sex in asymmetric changes in paired bones (Ruff and Jones, 1981). For these reasons, the results of Pfeiffer's work cannot reliably be compared with the present results.

The results presented in table 5.7 demonstrate a small but definite trend for the dimensions of the humerus to increase with age on both sides. In addition, the midshaft maximum is 2.8% larger on the left side for the Mature Adults than for the Young Adults; the horizontal dimension of the greater tubercle is 2.9% larger on the left and 2.4% larger on the right side than for the Young Adults. When asymmetric differences in each age group are compared, by subtracting each left side mean from each right side mean for all measurements in table 5.7, then asymmetry is seen to decrease with age in 9 of the 11 measurements. Thus, although some dimensions <u>increase</u> most asymmetries <u>decrease</u> with age in these results. Ruff and Jones (*ibid.*) demonstrated similar findings in their sample of 30 males and 39 females. They proposed two factors which may cause loss of bilateral asymmetry with ageing. Firstly, a decline in asymmetry may help to re-distribute bone in such a way "as to partially offset the effects of.....loss of total skeletal mass and volume with aging" (p 82). Secondly, if bilateral asymmetry reflects an asymmetrical use of the limbs and results in a hypertrophy of the dominant limb then an increasingly symmetrical use of the limbs and a reduction in activity levels with age might explain the decrease in asymmetry. Clearly, the present results support these ideas.

The sign tests for the humeral indices were applied to the two age groups separately. For the Young Adults, the results were almost identical to those for the site subsamples. The midshaft and tubercle indices showed a non-significant difference in favour of the left side, the lesser tubercle index showed a non-significant difference in favour of the right side, as in the *Mary Rose* sample. The robusticity index showed a significantly right-sided dominance, as it did in the Norwich sample ($p = 0.01$). None of the indices showed any statistically significant differences between the sides for the Mature Adults.

The X-ray data for the age groups were analysed by the application of two different tests. Firstly, the ratio'd measurements were analysed by application of the sign test and, secondly, t tests were applied. The results of the sign test for the Young Adults showed right-sided dominance (for both measurements, $p = 0.001$, table 5.3). Note that the divers are included in the X-ray sample.

For the application of the t tests, X-ray data for the age sub-sample were divided in two groups, the Young Adults and the Mature Adults. This was done in order to examine and compare the data from the sample of 49 humeri from the modern divers. These individuals were all less than 30 years of age and therefore placed in the Young Adult sample (see chapter 3). The tests compared the data for the Young Adults from the two archaeological groups (which were put together for these tests) and the data for the divers, for each side separately (see table 5.9).

The results of these tests demonstrated highly significant differences between the divers and the archaeological samples (table 5.9). These differences showed that the divers' humeri were larger by a substantial amount on both sides. In the total subperiosteal diameter the divers were larger by 11.7% on the left side and 10.2% on the right side than the pooled archaeological samples. In the medullary cavity width, the divers were larger by 13.5% on the left side and 12.8% on the right side. The total cortex was statistically significant only on the left side between the groups and was 8.3% larger in the divers' humeri, while the cortical area was 19% larger on the left side and 14.6% larger on the right side in the group of divers. These large differences require explanation.

Initially, it was assumed that the results might have arisen from a magnification error, even though efforts were made to correct for this (see chapter 3). This assumption was reinforced by the results of the analysis for the Young Adults from the two archaeological sites alone. In these results there were no significant differences in any of the measurements and derivations. The corrections for magnification for the divers' humeral X-rays had included a 5 cm allowance for the distance from the film pack of the living bone due to the soft tissue. This gave a magnification correction factor of 1.05. It was decided to re-calculate the mean for the total subperiosteal measurement on the divers' bones by doubling the suggested bone/film distance to 10 cm. This gave a magnification correction factor of 1.11. The procedure was as follows (the data are taken from table 5.9.1 for the left side):

Corrected Subperiosteal diameter, divers' mean = 27.82 ± 1.95

Uncorrected " " divers' mean = 29.21 ± 2.05

New corrected " " divers' mean = 26.32 ± 1.84

Subperiosteal diameter, archaeological mean = 24.55 ± 1.86

Difference between the new corrected divers' and the archaeological means = 1.77

% difference between the new corrected divers' and the archaeological means = 6.7%

Clearly, even when the magnification correction has been doubled, which seems unreasonable, the divers are still larger by about 7% than the archaeological sample. This difference, therefore, does not appear to be an artefact of the method.

As part of his study of the 1960 Rome Olympic athletes, Tanner (1964) took a series of measurements from X-rays. One of these was the diameter of the humerus. The bone was positioned in the same orientation as that employed for this study and was about 5 cm away from the film (p 29). Therefore, the results should be comparable directly with those from the present study. Accordingly, the athletes were divided into the same age groups as those used here; those under 30 were classified as Young Adults and those of 30 or more as Mature Adults. Comparison was made of the mean measurements for those athletes who were engaged in discus, shot put, javelin, hammer, weight lifting and wrestling, with the mean measurements from the divers. The results from the athletes for the left side only were as follows for the Young Adults:

Total subperiosteal diameter for:

a) the whole group: N = 77; Mean = 24.33 ± 2.68

b) Shot put: N = 7; Mean = 27.71 ± 1.73

c) Discus + shot put: N = 9; Mean = 28.11 ± 1.85

The results for groups b) and c) are clearly comparable with those from the divers even when the latter are uncorrected, although the samples are small. Therefore, the X-ray film-to-bone allowance of 5 cm would appear to be acceptable.

Since the increase in dimensions of the divers' bones does not appear to be an artefact of the X-ray technique or measuring method, it requires another explanation. In order to be accepted and to continue as a diver, a man in the Royal Navy is required to be at the peak of physical fitness (Jarvis, 1989). It is also a reasonable assumption that the diet of men born during the last 30 years will have been considerably better than that of most medieval men. While one of the exceptions may have been the crew of the *Mary Rose* (see next section), a modern diet is expected to be superior. The larger measurements of the divers may thus be a reflection of levels of fitness and of improved diet. The results may also be influenced by activity but this parameter is unknown.

Various authors have discussed the reaction of bone to levels of activity. Jones *et al*. (1977) X-rayed 48 male and 30 female professional tennis players. Their work demonstrated an increase of 34.9% in the cortical thickness of the playing arm of males and an increase of 28.4% in the playing arm of females. The hypertrophy of the bone apparently involved both the subperiosteal and endosteal margins. The authors state that their work: "....strongly supports the conclusion that exercise can promote bone hypertrophy" (p208). Watson (1973) studied the humeri of 203 amateur baseball players using photon absorptiometry. He found a consistent pattern of dominance in the humerus for all the bone variables which were tested, while the corresponding bones of the forearm did not demonstrate the same pattern of dominance. In the Young Adults from the present study, there is only one example of an asymmetric change between the divers and the archaeological samples. The total cortex is significantly greater on the left side ($p = 0.02$) for the divers. Although also greater on the right side, it is not significantly so ($p = 0.21$). Ruff and Jones (1981) found this measurement to be significantly larger on the right in male humeri, and Watson (*ibid.*) demonstrated the same result in the dominant (presumably right) humerus. The results of the present research are different. While it would be capricious to suggest that there might be a preponderance of left-handed divers in the sample, it is not clear how this single result can be explained.

6.2.4 Conclusions for the Humerus.

The dimensions of the humerus have been analysed for four samples, the two archaeological sites and the two age groups. The following may be inferred from the results:

The Sub-Sample for Site.

The pattern of asymmetries in the archaeological samples demonstrated that the men in the Norwich sample were more asymmetric than the men in the *Mary Rose* sample. All asymmetries showed a right-sided dominance. When correlated with humeral length, as a measure of size, the relationship between asymmetry and size was shown to be significant but weak. Thus, less than 50% of the relationships were due to size alone. Therefore, the larger proportion of the asymmetries were due to other factors, probably related to function. Since the asymmetries all showed a right-sided dominance, and since >90% of the species is right-handed, this pattern of asymmetries is probably due to handedness. Only one measurement in the *Mary Rose* sample, the greater tubercle, showed this significant right-sided asymmetry, although the majority of the measurements showed a non-significant bias in favour of the right side. It is possible that the men in this sample were, generally, using their arms more equally. The *Mary Rose* men were larger than the Norwich men in most dimensions and there were significant differences between the groups in the dimensions of the left shoulder. The long-term activity of a professional modern archer produces hypertrophy of the left shoulder; continued use of a heavy medieval long bow induces pain and stress in the same area. It is suggested that the larger left greater tuberosities of the *Mary Rose* men, when compared with the Norwich men, could reflect a group of archers present in the sample.

The robusticity index demonstrated a right-sided dominance for the Norwich group. The index showed an equal distribution between the arms in the *Mary Rose* group, as did the midshaft index. This suggests an equal use of the arms in this sample, supported by the general lack of significant asymmetries.

The X-ray results demonstrated large differences in the amount of cortex on both sides between the sites. The *Mary Rose* men were bigger. It is suggested that this may indicate some initial selection process of the crew, possibly for specific skills, in addition to the long-term practice of particular activities or occupations. These results are for the Mature Adults only. The comparison of the X-rays with the muscle scores only demonstrated significant differences for the Young Adults. These results suggest an equal use of both arms.

The Sub-Sample for Age.

While two dimensions demonstrated increases with age, most asymmetries demonstrated decreases with age. This agrees with other work.

The robusticity index demonstrated a right-sided dominance in the Young Adults but not in the Mature Adults. The results of the X-rays demonstrated a decrease between the two groups with age. It is suggested that all these results support the idea of a 'balancing' process occurring in the skeleton during ageing; there is a physiological re-distribution of bone together with an increasingly symmetrical use of the upper limb with increasing age.

X-rays for the Young Adults only demonstrated large differences in values between the modern divers and the archaeological samples. These differences did not appear to be a function of magnification error or of the technique used. It is suggested that the differences are authentic, and probably due to a superior modern diet and level of general health and fitness. However, the left-sided dominance in total cortex which occurs in the divers sample disagrees with other work and cannot be explained at present.

The results of the work on the humerus have confirmed and extended other findings in basic asymmetry and in age-related changes. The comparison between the archaeological sites has demonstrated differences that are probably due both to selection and to activity. The *Mary Rose* sample demonstrated an intra-group lack of asymmetry but an inter-group increase in dimensions, particularly of the left shoulder. The literary evidence supports the contention that these increases are due to levels of activity. The pattern of asymmetries in the Norwich sample are probably due to handedness. The increase in the divers' X-ray dimensions suggests the importance in this group of selection for fitness (Jarvis, 1989) and of a modern diet. Finally, the analysis of the asymmetries in the whole, combined sample was biased by the size of the sample from Norwich.

6.3. THE FEMUR.

6.3.1 The Whole Sample.

The dry bone sample consisted of 112 pairs of femora from both age ranges and from both archaeological sites. Unlike the humerus the archaeological samples of femora were similar in size (57 and 55 pairs respectively). They could, therefore, be pooled and analysed together without the introduction of any bias due to inequality of sample size. Correlation coefficients were calculated for the whole sample and for the archaeological subsamples in the same way as for the humerus (Appendix III).

Of the twenty one measurements taken on the paired femora, four proved to be significant at the $p < 0.05$ level or better (table 5.2. Note that only three significantly asymmetric measurements are shown in the table; this will be discussed). There was a variation in the dominant side, with the left side larger in three of the measurements and the right side in one. This variation may be seen throughout the results for the whole group, although they are, largely, statistically non-significant. Here, eleven of the twenty one measurements demonstrated a left-sided dominance and ten demonstrated a right-sided dominance. Although not part of the X-ray work *per se*, two of the significant measurements were taken from radiographs. These were the length of the head and neck, and the angle of the head and neck to the axis of the shaft. The latter measurement showed a level of significance of $p < 0.07$ by the sign test (see Table 5.2). However, an earlier t test had produced a level of $p = 0.04$ and it was, therefore, decided to include this measurement with the statistically significant results. Both the angle ($p = 0.04$) and the length of the head and neck ($p < 0.005$) demonstrated a dominance of the left side and so did the length of the medial condyle ($p < 0.005$). The maximum dimension of the greater trochanter, however, showed a right-sided dominance ($p < 0.0005$).

Correlation coefficients were calculated for each side separately for all the samples. As with the humerus, the level of significance had to be at least 0.05. For the whole femoral sample at this level of significance, the critical value of Pearson's r had to be equal to or more than 0.195.

The measurements which had low, non-significant correlation coefficients were those involving the neck/shaft angle and those involving the lesser trochanter (see Appendix III a). On the left side, the neck/shaft angle showed low correlations with every measurement except the mediolateral popliteal diameter, and on the right side with every measurement except both of the longitudinal ones (L1 and L2) and the greater trochanter. This angle also showed a low correlation with the length of the head and neck on both sides thus demonstrating, perhaps surprisingly, that there is no significant relationship between these two measurements. Of the asymmetric measurements, the neck/shaft angle also was clearly less significantly different than the other three measurements. The lesser trochanter demonstrated a non-significant correlation with 14 measurments on the left side and with 7 of these same measurements on the right side (Appendix III a).

The four significant femoral asymmetries are the length of the medial condyle, the greater trochanter, the neck/shaft angle and the length of the head and neck. If the physiological length is taken as measure of size (in the same way as the maximum length of the humerus) the asymmetries may be correlated with this measure for each side. The results are presented in table 6.2.

TABLE 6.2

CORRELATIONS OF BODY SIZE AND ASYMMETRY: THE FEMUR.

TABLE 6.2.1: THE WHOLE SAMPLE.

Femoral physiological length is correlated with:

	Left	Right
Length of the medial condyle:	0.604	0.631
Greater trochanter:	0.378	0.381
Neck/shaft angle:	0.136*	0.307
Head/neck length:	0.456	0.559

* = non-significant

Using values of Pearson's *r* for a one-tailed test, it can be seen that all the results except one (the neck/shaft angle on the left) are significant at the $p = 0.025$ level or better. Therefore, there is a weak but significant relationship between size and asymmetry in three of the four femoral dimensions. The neck/shaft angle, however, shows no relationship with size at all on the left side and only a very weak one on the right side (0.09% of the relationship due to size). If the neck/shaft angle shows such a marked lack of relationship with femoral size, what does influence it?

Kapandji (1983) discussed two types of femoral head shape and neck/shaft angle, stating that the shape of this area of the bone is the result of a functional adaptation. In his Type I, the angle is maximal at 125^0 and the head is 2/3 of a sphere. This adaptation is said to be related to speed of movement (p24). Type II has a lower angle of 115^0 and a more hemispherical head. The adaptation here is for strength or power. Both adaptations also involve the shape of the pelvis and femoral shaft. Aiello and Dean, however, (1990) argued that the interrelationships of the features in this area of the femur and their mechanical significance have yet to be established. Trinkaus (1976) had a mean value for the neck/shaft angle in modern *Homo sapiens* (Europeans) of 128.5^0 (n=50, his table 4). He argued that a lower angle is associated with high levels of activity and mechanical stress at the hip. While the hip is strengthened, the diaphysis is stressed, a relationship which is supported by a "strong negative correlation between neck/shaft angle and midshaft transverse diameter" (p294).

In the present sample, the neck/shaft angle had a mean of 126.4^0 (Appendix I b). This is within both the modern range and within 1 standard deviation of Trinkaus' mean. There is also a strong negative correlation between the angle and the midshaft transverse diameter on both sides (Appendix III a). The implication of these results is that some members of the sample were involved in high levels of activity. This will be discussed further in the subsample for site.

Many of the femoral measurements for the whole sample showed a highly significant correlation with each other at the $p = 0.001$ level or better. The most highly correlated on both sides were the maximum and physiological lengths, the pilastric and circumferential measurements and the condylar measurements. This was anticipated, since the measurements are taken in the same areas of the bone for each of these three sets. Thus, as one dimension (such as L1) increases in size so will the other (such as L2). The greater trochanter was significantly correlated with every measurement on both sides. The highest of these correlations was with the bicondylar breadth. Thus, it would appear that an increase in size of the greater trochanter is accompanied by an increase in bicondylar breadth. Although significantly correlated, however, most of these relationships were weak ones. When the coefficients are squared it can be seen that, in most cases, less than 50% of the relationships can be explained by size alone. The neck/shaft angle has been discussed. How can the other results be explained?

In their 1965 study of 105 Asian skeletons, Latimer and Lowrance found that the bones of the right arm "*in general*" were longer and heavier than those on the left. In the lower limbs, however, this was not the case. Here, the authors demonstrated that there was more uniformity in the sizes of pairs of bones although "The femur is the most constant in its greater weight and length on the left side" (p223). Chhibber and Singh (1970) showed that the left lower limb was heavier in seven instances and the right in three instances for ten adult cadavers. They argued that this difference in weight "is believed to be the result of functional dominance of one limb over the other (as in the upper limb)" and found a "highly significant" ($p < 0.001$) difference in weight between the dominant and non-dominant sides (p556). Schultz (1937) measured 100 white male femora. He demonstrated that the right femur was longer than the left in 28 cases, both were of equal length in 20 cases and the left femur was longer than the right in 52 cases (table 15, p309). When comparing all groups and both sexes, Schultz found that the left side in the lower limb was more frequently dominant than the right side. He also found that this dominance was not as marked in the lower limb as it was in the upper limb. In the present results, the maximum length of the left femur was frequently greater than the right, although the difference was not statistically significant ($p < 0.2$). The results for the physiological length were similar ($p < 0.5$). These results are in accord with those from previous studies, and both the longitudinal measures are also highly intercorrelated in the present results.

Three of the four significant femoral asymmetries occurred in the proximal portion of the bone; the fourth affected the length of the medial condyle. Brothwell (1991) has suggested that a long bone may be considered as a shaft and epiphyses with a varying blood supply. (The area of the diaphysis adjacent to the epiphysis is particularly vascular (Johnston *et al.*, 1958, p27). In states of malnutrition, it is the epiphyses which become most growth-retarded. Might conditions of physical stimulation therefore have an opposite effect on them and is it thus possible that the dimensions related to the epiphyses might show more variation (asymmetry) than those related to the shaft?

The epiphyses contain the secondary centres of ossification; they are situated above the growth plate (Resnick and Niwayama, 1981, p17). Growth may be delayed by hormonal insufficiency, for example as in hypothyroidism. Although the mechanism controlling the rate of skeletal maturation is hormonal, the balance of hormones involved is unclear (Harrison *et al.*, 1988, p379). Growth is also delayed by malnutrition. Providing the period of malnutrition is brief, however, a "catch-up" phase of growth occurs during which weight, height and skeletal development all attain the normal growth curve again (*ibid.*, p387). At skeletal maturation "the epiphyses of the long bones close completely and cannot afterwards be stimulated to grow again" (*ibid.*, p357). It follows therefore that, while brief periods of malnutrition will affect the epiphyses as they will affect growth in general, the epiphyseal areas will recover again, along with the rest of the skeleton. It is unlikely, therefore, that the epiphyses in the adult will show the variation Brothwell suggests unless there have been periods of such severe starvation that the skeleton could not recover. Similarly, any physical stimulation that might permanently affect the dimensions of the epiphyseal areas would have to be both extreme and protracted in the immature individual.

MacLaughlin (1987) stated that "....epiphyses respond more directly to musculo-skeletal activity than any other region of the bone" (p111). In contrast, in his study of 100 pairs of male femora, Ingalls (1924) found the epiphyseal areas to be "the most constant part of the bone" with little variation between the sides. Resnick and Niwayama (1981, p18) state that : "Although subtle changes in size and shape of the articular ends of bone have been demonstrated in adults, *the mechanisms are unknown*" (my italics). The medial condyle is part of an epiphysis and is articular, as is the femoral head. The greater trochanter is a non-articular epiphysis. Clearly, the mechanisms governing their side differences in the present sample are unknown. They will be discussed further in the sections on the sub-samples.

The results of the tests on the femoral indices demonstrated a single statistically significant side difference, the platymeric index ($p < 0.01$, table 5.6). This index, the robusticity index ($p < 4.4$) and the index of bowing ($p < 2$) were all greater for the right side. The pilastric and popliteal indices were both greater for the left side. The pilastric index was just outside the chosen level of significance ($p < 0.07$). It is derived from the midshaft dimensions of the femur, as is the robusticity index, and it expresses the degree of 'pilastering' present in the femur. The pilaster is a structure which supports the linea aspera down the posterior side of the bone. It may exist with or without a linea aspera, and appears in late childhood or adolescence (Aiello and Dean, 1990, p466). The platymeric index describes the subtrochanteric anteroposterior flattening of the shaft at the proximal end. Therefore, these two indices describe the shape of the femoral shaft at the proximal and midshaft positions. Clearly, the right femur is significantly flatter at the proximal end while the left femur is more pilastric in this sample.

When the sign test was applied, there were no statistically significant differences between the sides in the X-ray measurements (table 5.4). This was true for the whole sample and for both the sub-samples. The correlation coefficients demonstrated that many of the measurements were highly significantly correlated. These results, and the others discussed in this section, corroborate previous research which found fewer differences between the sides in the femur than in the humerus.

6.3.2. The Sub-Sample for Site.

The sub-sample constructed in order to compare the archaeological sites consisted of 55 femora from the *Mary Rose* and 57 femora from Norwich. Stature was estimated using the left femur and compared between the two archaeological sites. The results demonstrated a significant difference ($p = 0.001$, table 5.8) of 2 cm between the means of the two groups, showing that the men from the *Mary Rose* were taller than the men from Norwich. Are there any possible explanations for this small but significant difference in mean stature?

The *Mary Rose* was the flagship of King Henry's fleet and it has been assumed that her crew was specially selected and, therefore, the "cream" of the young male population, (Rule, 1991). Evidence for this assumption does not exist. However, it is unlikely that stature *per se* would be a criterion for selection. Hannay (1898, p38 *et seq.*) stated that there was a regular staff of pilots, boatswains and gunners who belonged to the whole navy and not necessarily to a specific ship. The crews could be impressed and were contracted for only three months at a time (*ibid.* p 41). Is it possible to evoke dietary differences between the two sites? Apart from the ship's officers, many of whom became Gentleman at Court when not in service, the diet of "ordinary" people was probably similar in East Anglia and southern England during the medieval period. A protein-rich, high meat diet was known to have been enjoyed by the upper levels of 16th century society. The basic subsistence for the rest of the people consisted of cereals and pulses, with milk and some butter, (Green, 1991). Very little meat was consumed. However, the archaeological evidence suggests that a great deal of meat was consumed on the ship, since many barrels of butchered carcasses were found (Coy, 1984); there was no evidence for either grains or pulses as a food source on the ship (Green, *ibid.*). Davies (1964) discussed the provisioning of the King's army in 1544, stating that the troops "...were certainly not skimped" (p234), while Rosen (1939) listed the weekly allowance for a British seaman during the seventeenth and eighteenth centuries (p753). It is clear from this list that the diet was varied in form and considerable in volume. The evidence implies that the crew enjoyed a richer diet than that of the majority of the population, at least while on board the ship. In contrast, the group from Norwich were buried in the poorest medieval parish in the city, which perhaps implies that their life styles, including diet, were similar to the poorer levels of the main population. However, there were improvements in diet for some sectors of the population (harvest workers) from the early medieval to the post medieval periods, as represented by these two sites (Dyer, 1988). The *Mary Rose* sample may be reflecting these improvements by their increased stature.

One can hypothesise that the crew of a ship such as the *Mary Rose* was largely composed of a group of 'professional' men who were initially enlisted either for their skills or as part of a general programme of 'manning the King's ships'. They could then, perhaps, expect to be members of the crew over a long period of time. What is the evidence for this hypothesis? While differences in stature could imply a better diet from an early age for one group than for another, improvements in diet after the epiphyses have fused and growth has ceased will not effect stature. The evidence from the original analysis of the human skeletal remains from the ship suggests that the excavated element (~ 40%) consisted of a number of adolescents and young adults, with unfused or just fused epiphyses, together with a smaller group of older men. If the greater stature of the men from the *Mary Rose* implies that they were better fed than the majority of the population, then their improved diet must have been available to them on a long-term regular basis. The implication of this suggestion is that the crew of the *Mary Rose* was more permanent in nature than has been assumed (Hannay *op. cit.*). It is impossible at the moment to confirm either this suggestion, or to confirm whether the crew were reflecting a secular improvement in diet which affected the Tudor population generally.

The results of the t tests (table 5.8) provided eleven measurements which showed statistically significant differences between the archaeological sites. Of these, seven demonstrated significant differences between the sites on both sides, one on the right side only, and three on the left side only. Four of these significant measurements involved the longitudinal dimensions of the bone. They demonstrated that the sample from the *Mary Rose* was larger than the sample from Norwich on both sides for the following: the maximum length ($p = 0.01$ on the left and 0.02 on the right side); the physiological length ($p = 0.01$ on the left and 0.03 on the right side; these two measures were closely intercorrelated for both sites); the chord of bowing ($p = 0.0004$ on the left and 0.001 on the right side); subtense of the chord ($p = 0.05$ on the left and 0.01 on the right side). Two of the significant dimensions involved diameters of the bone: the subtrochanteric anteroposterior diameter on the right side ($p = 0.01$) and the mediolateral popliteal diameter ($p = 0.01$ on both sides). In the proximal part of the bone two dimensions demonstrated significant differences on both sides, the maximum dimension of the greater trochanter ($p = 0.01$) and the length of the head and neck ($p = 0.01$). At the distal end, the bicondylar breadth ($p = 0.01$), the length of the medial condyle ($p = 0.03$) and the breadth of the lateral condyle ($p = 0.05$) all showed significant differences on the left side. The sample from the *Mary Rose* were larger than the sample from Norwich for all these dimensions. Indeed, the *Mary Rose* sample was larger than the Norwich sample in all but two femoral dimensions : the angle of the head and neck on the left side and the anteroposterior popliteal diameter on the right side (table 5.8).

The lower value of the neck/shaft angle in the *Mary Rose* sample is of particular interest (mean = 124.7^0 on the right side). There are also stronger negative correlations between the angle and the midshaft transverse diameter in the *Mary Rose* sample than in the Norwich one (Appendix III b and c). These relationships have already been discussed for the whole sample. Following Trinkaus (1976), it appears that the *Mary Rose* men probably were involved in higher levels of activity than the Norwich men. Furthermore, the paired femora were longer for the *Mary Rose* group than they were for the Norwich group, hence the increase in stature. If the femoral lengths increase as a result of an improvement in diet, then this improvement can affect other dimensions of the bone. Similarly, these differences in dimensions may reflect a selection process. The

Mary Rose men may have been chosen because they were large.

Two dimensions which show statistical significance will be considered further. Firstly, the bilaterally significant values for the chord of bowing and its subtense may be a reflection of a pathological childhood condition. The femora from the *Mary Rose* sample appeared to be more bowed anteroposteriorly than those from Norwich when examined originally. Some of them were so bowed as to suggest that the individuals had suffered from childhood rickets. In addition, a number of tibiae were bowed mediolaterally, also suggesting some of the sample had suffered from rickets in childhood. The significance of the chord of bowing and its subtense support this idea. These two measurements also showed low correlations with many other measures.

Secondly, the increase in the greater trochanter for both sides in the sample from the *Mary Rose* might be attributable to increased activity by gluteus medius and gluteus minimus. As the controllers of pelvic tilt (see chapter 3) these muscles would have to work hard on a ship with a small keel and little ballast as the crew would be striving to keep their balance. Since both muscles insert onto the greater trochanter, the increased dimensions of this trochanter for the *Mary Rose* sample may be an indication of the greater use of these muscles by this group and, hence, increased activity.

None of the femoral indices showed any statistical significance between the two archaeological sites. The platymeric and pilastric indices, however, were larger on the right side for both groups.

The results of the tests applied to the X-ray measurements for these two sites demonstrated significant differences between the sites for the Young Adults only (table 5.12). Two dimensions showed significant differences: the total subperiosteal diameter on both sides ($p = 0.04$) and the medullary cavity width on the right side ($p = 0.02$). The sample from the *Mary Rose* were larger in both cases. It is probable that these results reflect the general increase in dimensions of the femora from the *Mary Rose* which have been discussed above.

The 'non-metric' traits of the femur will be discussed extensively in the section dealing with the age samples. When compared by archaeological site only one of them, the third trochanter, showed statistically significant differences between the groups. The *Mary Rose* sample demonstrated a higher frequency ($p = 0.03$) on the right side than Norwich. Although not statistically significant this 'trait' was also more frequent ($p = 0.2$) on the left in the *Mary Rose* sample. This difference between the groups probably reflects a greater use of the gluteal muscles by the ship's crew, particularly in view of the increase in the dimensions of the greater trochanter already discussed. Some or all of these muscles will be used in activities such as maintaining balance and climbing.

Only the Mature Adults from Norwich showed significant differences in the ranked muscle scores and the amount of cortex present in the femur (table 5.15). Significant results were obtained for the following (both were on the left side):

Cortical area / gluteus maximus $p = 0.01$
Cortical area / adductors & vasti $p = 0.04$

The largest cortical area is matched with the highest score in both cases. It is difficult to explain these results. However, as was the case for the humerus, it is important to remember that muscles do not work in isolation but in co-operation with others. Their individual scoring may be of little significance.

6.3.3. <u>The Sub-sample for Age.</u>

The sub-sample constructed for age consisted of 64 pairs of Young Adult and 48 pairs of Mature Adult femora (see chapter 3). They were not further sub-divided into age categories for the archaeological sites. However, as with the humerus, an exception was made for comparison of the X-rays between the archaeological sites.

Stature was estimated as described in chapter 3. Due to the commingling of the *Mary Rose* sample stature for a single individual could not be reliably estimated using the humerus and the femur separately. Therefore, it was decided to use the bone which demonstrates the lowest standard error when regression equations are applied to estimate stature (Trotter, 1970). In each case the left femur was measured and stature was calculated using the regression equations for adult white males (*ibid.*). Comparisons of stature were made between the groups in the two sub-samples. There were no significant differences in height according to age (p = 0.31, table 5.8). Differences according to site have alredy been discussed.

When examined by age groups the Mature Adults were larger than the Young Adults in all but four dimensions (table 5.8). These were: the maximum dimension of the lesser trochanter and the chord of bowing on the left side; the length of the head and neck on the left side; the subtense of the chord of bowing on both sides. Seven of the femoral dimensions produced statistically significant differences. Three of these were shaft diameters; they demonstrated that the Mature Adults were larger than the Young Adults on both sides for the following: the mediolateral pilastric diameter (p = 0.01 on the left and 0.02 on the right side); the mediolateral popliteal diameter (p = 0.05 on both sides); the maximum circumference midshaft (p = 0.05 on the left and 0.04 on the right side). At the proximal end the diameter of the head demonstrated a difference of p = 0.01 on the left side and 0.03 on the right side. At the distal end the differences were on one side only: the bicondylar breadth on the right side (p = 0.05); the length of the lateral condyle on the right side (p = 0.03); the breadth of the lateral condyle on the left side (p = 0.04). In all instances the Mature Adults were larger than the Young Adults. How may these differences be explained?

In her study of 257 individuals from the Terry collection, Eriksen (1979) included Blacks and Whites of both sexes with an age range of 20 to 90 years. In order to evaluate the medullary cavity of the femur a series of measurements were taken at a number of sites in the proximal third of each pair of bones. Two of these measurements were the "external anterior-posterior" and the 'external medial-lateral" diameters. The relationship between each measurement and age was examined. The mediolateral diameter was found to increase with age in males. In the present results, the mediolateral pilastric diameter was 3.2% larger on the left side and 2.8% larger on the right side in the Mature Adults than in the Young Adults; the mediolateral popliteal diameter was 2.9% larger on the left side and 3.1% larger on the right side in the Mature Adults. These results are in agreement with those of Eriksen. The midshaft circumference was measured at the same position as the pilastric diameters. It was 2.3% larger on the left side and 2.5% larger on the right side for the Mature Adults. The anteroposterior pilastric diameter showed a non-significant increase for the Mature Adults on both sides (table 5.8); the mediolateral pilastric diameter has already been discussed. It is obvious that the larger values for the Mature Adults in the midshaft circumference are related to the increases in values of its constituent measurements. All three dimensions therefore demonstrate increases with age.

The remaining four dimensions which demonstrated an increase with age are in the region of the epiphyses. In the whole sample, the length of the medial condyle showed a significant left-sided dominance. In the age sub-sample, the length of the lateral condyle demonstrated a significant right-sided dominance ($p = 0.03$), while its breadth showed a significant left-sided dominance ($p = 0.04$). The bicondylar breadth was significantly different between the two age groups on the right side ($p = 0.05$). There appear to be no patterns either in the results for these distal epiphyseal areas or in the proximal part of the bone, where the diameter of the head demonstrated an increase on both sides with age (the Mature Adults were 2.5% larger on the left and 2.2% larger on the right than the Young Adults). The effects of various stresses on the epiphyses was discussed in the section on the whole sample. Perhaps the results from these epiphyseal areas confirm the lower asymmetry reported in the literature for the femur.

The results for the humerus demonstrated a small but definite trend for dimensions to increase with age on both sides. A similar pattern has been found for the femur. However, when asymmetric differences in each age group were compared for the humerus, asymmetry was seen to decrease with age. Thus, although some dimensions were seen to increase, most asymmetries were seen to decrease with age. Does this also occur in the femur? The mean of each right side femoral measurement was subtracted from the mean of each left side measurement. The results showed that for the original twenty one measurements ten were less asymmetric for the Mature Adults and eleven were less asymmetric for the Young Adults. Therefore, only about half of the asymmetries decrease with age in the femur. Thus, in this sample, more dimensions increased and fewer asymmetries decreased with age in the femur than in the humerus. These findings do not appear to have been considered previously.

It has been shown that the femur is less asymmetric than the humerus. Congenitally, the lower limbs appear to be more equal in length than the upper limbs. There appears to be a more even use of the lower limbs (for bipedal walking) than there is of the upper limbs, where preferential use enhances congenital asymmetry. Because the femur is more symmetric and more evenly loaded, possibly less physiological re-distribution of bone is required with age. Thus, asymmetries do not decrease with age in the femur as they do in the humerus. The increase in dimensions with age in the femur may be related to subtle biomechanical changes in a bone which is loaded for a large proportion of its lifetime.

The results of the tests on the femoral indices between the two age groups produced no statistically significant differences between them. In both age groups, however, the pilastric index was greater on the left side ($p < 2.2$ for the Young Adults and < 0.7 for the Mature Adults). Both platymeric indices demonstrated the same level of significance ($p < 0.5$) and both were larger on the right side. While non-significant, both these results follow the same pattern as for the whole group.

The lack of statistical significance in the results of the sign tests for the X-ray measurements in all three groups has already been discussed. In order to incorporate the sample of 50 femora from the modern divers in the t tests, X-ray data for the age sub-sample were divided in two groups, the Young Adults and the Mature Adults. The divers were placed in the Young Adult sample (see chapter 3). The tests compared the data for the Young Adults from the two archaeological groups with the data for the divers. Both sides were compared separately. In a different test, the data for the Young Adults from the two archaeological groups alone were also compared. There were no significant differences in the results for the Mature Adults from the two archaeological sites.

Table 5.11 presents the results of the t tests applied to the X-ray measurements for the Young Adults from the archaeological sites and the divers. These results demonstrated significant differences between the divers and the archaeological samples. The divers' femora were significantly larger in three dimensions. In the total subperiosteal diameter the divers were 4.3% larger on the left side and 5.2% larger on the right side than the archaeological sample. In the medullary cavity width the increases were 10.7% on the left side and 11.6% on the right side. Cortical area demonstrated an increase of 5.8% on the right side only. Such differences in favour of the divers were anticipated following the results for the humerus. The other statistically significant difference between the groups was the percentage of cortex which showed an increase of 5.9% on both sides but for the archaeological samples. It is perhaps surprising to find that the percentage of cortex has increased whereas the amount of cortex present has decreased, for the archaeological samples.

Percent cortex is defined by the following equation:

$$\% C = (T-M)/T \times 100$$
$$= (1-M/T) \times 100.$$

Both T and M are larger for the divers than for the archaeological groups. But, M/T must be smaller for the archaeological groups if %C is to increase. Hence, either M is less and/or T is greater. Since T for the archaeological groups is less than T for the divers (see table 5.11) then M must also be smaller for the archaeological groups. So, although the archaeological samples exhibit a larger <u>percentage</u> of cortex present, they do not have a greater <u>thickness</u> of cortex.

Possible reasons for the increased dimensions in the divers bones were fully discussed for the humerus. The X-rays measured from the divers' sample consisted of pairs of humeri and femora from each individual. Several suggestions for the increased dimensions of the humerus in the divers' sample may also be made for the femora. They include a high level of health and fitness (Jarvis, 1989) and a superior diet.

Morphological traits traditionally recorded on the proximal femur have also been termed discontinuous or 'non-metrical' traits. They cannot be evaluated metrically but are scored on a present/absent basis (see Finnegean, 1978). The variations represented by the traits have been used to imply close genetic relationships in skeletal samples, particularly with cranial traits. Unfortunately, little is known about the inheritance of such features or the extent to which their frequencies may be modified by environment.

The traits which have been recorded here were discussed in chapter 3. They were analysed by application of the *chi* square test. The results showed that all the traits demonstrated a statistically significant difference between the age groups on both sides (table 5.16), with the exception of Poirier's facet. The third trochanter was significantly more frequent in the Young Adults (p = 0.001 on the left side and 0.03 on the right). The hypotrochanteric fossa was also significant in the Young Adults (p = 0.01 on the left and 0.05 on the right side), as was Allen's fossa (p = 0.04 on the left and 0.02 on the right side). Both Plaque and the exostoses in the trochanteric fossa were statistically significant for the Mature Adults. The former reached the same levels of significance for each side as Allen's fossa, while the latter reached p = 0.01 on the left side and 0.02 on the right side.

Angel (1964) discussed the area of the femoral neck in which plaque, Allen's fossa and Poirer's facet occur and called it the "reaction area". He suggested that this area does not develop in the femur as a result of any special body structure or posture but is the result of the interaction of certain dynamic factors. These factors are: ' primarily in the interaction of muscles (iliopsoas) and ligaments (zona) with gravity and leverage in extreme extension and secondarily in arrangement of ligament fibers in the capsule (crossing of the zona and the iliofemoral ligament)" (p139). The fossa is thus formed as a result of the dynamic relationships between the muscles and ligaments involved in the joint capsule. He argued that the fossa is formed in younger individuals by friction caused by ligamentous irregularity and that plaque is a later, often middle-aged hypertrophic response. Poirier's facet was considered to be related to "more vigorous muscle function" in males and to be a separate feature from the reaction area. In a study of Amerindian and cadaver femora Pitt *et al* (1982) demonstrated the existence of a "herniation pit" which underlies the reaction area in some femora. They discussed the origin of the area. Support for the idea of mechanical abrasion was provided by a positive correlation between the frequency of the anomaly and the thickness and roughness of the overlying capsule. The results of the present work clearly support these earlier findings. Allen's fossa is significantly present more frequently in the Young Adults on both sides and plaque occurs statistically more frequently in the Mature Adults. Assuming that these anomalies have a mechanical explanation, as suggested by previous work, they should not be considered as 'non-metric traits'. While they may have biological significance, they are not 'traits'. What can be said of the other recorded 'non-metric traits'?

The third trochanter or gluteal tuberosity is variable in its position at the top of the gluteal ridge. Gluteus maximus, which acts as an extensor of the hip and trunk, inserts on this ridge. The third trochanter can be oblong, rounded or conical in shape (Aiello and Dean, 1990, p465). It has been suggested that there may be a relationship between the presence of a pronounced third trochanter and a slight increase in platymeria (*ibid.*), although the present results do not support this view (tables 5.6 and 5.16). The 'third trochanter' has no epiphysis and is clearly not a separate trochanter. Given its association with the gluteal ridge and the insertion of gluteus maximus, it may be an expression of increased activity. This was discussed for the site subsample. Therefore, while this tuberosity may have some functional significance, there is no reason to assume it is a 'non-metric trait'.

The hypotrochanteric fossa occurs on the posterior lateral side of the femur, lying between the gluteal ridge and the lateral border. Finnegan (1978) stated that it was often found in close association with the gluteal ridge and the third trochanter. Aiello and Dean (1990) found that it occurred more frequently in children and juveniles than in adults. Although there are no juveniles in the present sample the fossa is more frequently present in the Young Adults than in the Mature Adults.

Exostoses in the trochanteric fossa occur at the site of the insertion of the tendon of the obturator externus muscle. Resnick and Niwayama (1981) have described such exostoses at osseous sites of tendon attachment as "degenerative enthesopathies" (p1297). They are common in older individuals. In the present sample, the exostoses demonstrate a significant increase in the Mature Adults. Clearly, they do so as a function of increased age.

The 'discontinuous non-metric' traits of the proximal femur have been shown to be influenced in their expression by several environmental factors. These include age and activity. Perhaps it is time to stop considering them as expressions of genetic relationships and to record and analyse them in terms of their environmental factors.

6.3.4 Conclusions for the Femur.

The dimensions of the femur have been analysed for three samples. The following may be inferred from the results for each group:

The Whole Sample.

The measurement of femoral torsion was tested and found to be unrepeatable (see chapter 3). Experimental work demonstrated that this technique is flawed. The points on the femoral head and neck necessary for consistent recording of angles of torsion cannot be identified from one bone to another. Thus, there is a wide variation in results. It has been demonstrated that it is not possible to measure the angles of femoral torsion with accuracy using present techniques.

Although the results were not significant, the maximum and physiological lengths were often found to be longer on the left side. These, the midshaft circumferential and the condylar measures were all closely intercorrelated.

Four of the femoral dimensions produced a statistically significant difference between the sides. Three of these demonstrated a left-sided dominance. The neck/shaft angle was within 1 standard deviation of Trinkaus' (1976) mean. It also demonstrated a strong negative correlation with the mediolateral midshaft diameter. These results imply high levels of activity for some sample members.

The dominant dimensions occurred in areas where epiphyses are present. Changes in epiphyses in the immature may be due to malnutrition or to activity. For such changes to be present in the adult, stresses must occur before epiphyseal fusion. The mechanisms for producing small differences to articular surfaces in adults are at present unknown.

Femoral indices demonstrated that the right bone was flatter proximally and that the left bone was more pilastric.

Dominance in the lower limb was less marked than in the upper limb. When present, it tended towards the left side.

The Sub-Sample for Site.

The men from the *Mary Rose* were taller than the men from Norwich; there is a difference of 2 cm in the mean stature of the two groups. It is suggested that this is a function of an improved diet before epiphyseal fusion. This dietary improvement may be due either to a better diet enjoyed on board ship or to a secular improvement enjoyed by the general Tudor population. If the former, it is suggested that this is evidence for a more permanent crew than has been historically postulated.

The men from the *Mary Rose* were significantly larger than the men from Norwich in eleven measurements, although there was no discernable pattern in these measurements. It is suggested that the improvement in diet, by whichever mechanism, which led to greater femoral length (as evidenced by the increase in stature) probably caused the increase in the other dimensions. Alternatively, the men might have been chosen because they were large. The lower neck/shaft angle and the strong negative correlation with the mediolateral midshaft diameter in this group implies that it was the men from the *Mary Rose* who were involved in higher levels of activity, rather than the men from Norwich.

The increase in the chord of bowing may be an expression of childhood rickets in the *Mary Rose* sample. The increase in the dimension of the greater trochanter suggests an increase in activity by the gluteal muscles, probably in maintaining balance. The increase in the presence of the third trochanter on the right side may be related to an increased use of gluteus maximus on this side. It is not clear why this should be asymmetric.

The sub-sample for Age.

There was no significant difference in height according to age.

While there was an increase in some dimensions with age (often on both sides), only about half of the asymmetries decreased with age. This is different from the results for the humerus. It is suggested that there is less requirement in the femur, than in the humerus, for a physiological re-distribution of bone with age, because of a lack of congenital asymmetry and a more symmetrical use over time.

The results of the X-ray measurements showed that the divers' femora were larger in three dimensions. The archaeological sample had a greater percentage of cortex. It was shown that, although the percentage is larger, the thickness is smaller. It is suggested that, as with the humerus, the increase in the divers' femoral dimensions is probably due to a superior modern diet and an increased level of health and fitness.

Environmental influences have been shown to affect the expression of discontinuous morphological traits. It is suggested that the presence of Allen's fossa and plaque are related to age and are mechanical in origin. The third trochanter may be related to levels of activity due to its association with gluteus maximus. The hypotrochanteric fossa occurs in the young and it is suggested that exostoses in the trochanteric fossa are a degenerative enthesopathy.

The pattern of asymmetries and of age and site related differences is less clear for the femur than for the humerus. This supports other findings on differences between these two bones. The comparisons between the ancient and modern groups have supported the possible importance of diet on the amounts of bone present. The comparison between the archaeological sites has demonstrated differences that may also be due to changes in diet. They may also reflect a selection process at work. Further work with other medieval and late medieval samples might help to answer some of these questions.

CHAPTER 7. SUMMARY AND SUGGESTIONS FOR FURTHER WORK.

7.1 SUMMARY.

The research which has been undertaken and discussed in this thesis sought to answer three questions (see chapter 1).

1. <u>To what extent is asymmetry exhibited by the humerus and the femur in the male skeleton?</u>

Earlier work on asymmetry in the upper and lower limbs has been expanded by the present results. Greater asymmetry has been demonstrated to occur in the humerus than in the femur. While a number of right-sided asymmetries have been demonstrated for the humerus, only maximum length appears to be congenital in origin. No congenital asymmetries have been demonstrated for the femur. The small number of asymmetries that occur in the femur are variable in their dominant side.

The difference in asymmetry between the limbs is of general anthropological interest. The results are probably related to bipedalism and the differential use and loading of the upper and lower limbs.

2. <u>What are the similarities and differences in asymmetry between the archaeological and the age groups?</u>

The Norwich men were more asymmetric in the humerus than the *Mary Rose* men. Asymmetry in the Norwich sample showed a right-sided dominance in every case; the single asymmetry in the *Mary Rose* sample was also right-sided. Although more symmetric, the *Mary Rose* sample demonstrated an increase over the Norwich sample in many dimensions, particularly those of the left shoulder. The *Mary Rose* sample also showed an increase in all but two femoral dimensions over the

Norwich sample.

Previous research has suggested that asymmetry decreases with age. The present results show that asymmetry decreases with age for most dimensions in the humerus. In the femur, however, only about half of the asymmetries decreased with age. In both bones a number of dimensions increased with age. More of these increases occurred in the femur than in the humerus, and usually on both sides. It is believed that this is the first report of this finding.

Different mechanisms appear to be operating for the upper and lower limbs. It has been suggested that a physiological re-distribution of bone may occur with age in the humerus and that this, coupled with an increasingly symmetrical use of the arms, will result in a decrease in asymmetry with increasing age. The present research suggests that such a re-distribution is unnecessary in the femur. The sides are congenitally more symmetrical and the use is more symmetrically 'balanced' than in the humerus. The increase in dimensions of the femur with age probably reflects remodelling due to persistent loading.

3. Are the asymmetries and differences present in the samples affected by size or by activity in either bone?

The present results indicate that humeral maximum length is probably enhanced by preferential use of the right limb, since at least 90% of the species is right handed. Right-sided dominance of humeral midshaft dimensions are also seen to reflect handedness. The new measurement of the humeral greater tuberosity, with its right-sided dominance, also reflects preferential use.

Although there is a marked dominance of the humerus by the right side there is no increase in cortex on the dominant side. These results do not support the idea that normal (rather than excessive) dominant use increases cortical bone. There is no enhancement of the maximum and physiological lengths of the femur by preferential use.

Correlation of asymmetries with size in both bones has shown that there is a significant but weak relationship between the two - bigger men tend to be more asymmetric. However, changes in dimensions have been shown to be due to factors in addition to size. Comparison of the two archaeological groups showed that the sample from the *Mary Rose* was larger in dimensions of the left shoulder than the sample from Norwich. It is suggested that these results may indicate the presence of archers in the group. (There were probably some archers present in the Norwich sample also. A conscript militia of well-trained archers, "compulsorily raised among the common people" (Trevelyan, 1967, p32) provided the core of the King's army during the medieval period. The Norwich cemetery was in use during the Battles of Crècy (AD 1346) and Agincourt (AD 1415), and during the Hundred Years War. However, it is suggested that the larger dimensions of the left shoulder in the *Mary Rose* sample implies the presence of a group of professional archers). Negative correlations of a low femoral neck/shaft angle and mediolateral pilastric diameter in the *Mary Rose* sample are similar to other results where a high level of activity has been suggested for these changes.

It is suggested that the 'non-metric traits' of the femur have environmental explanations. Those occurring on the neck appear to be mechanical in origin and are related to age in their expression. It is suggested that two others (the hypotrochanteric fossa and the exostoses in the trochanteric fossa) also express age-related changes. The 'third trochanter' may be related to an increased use of gluteus maximus, corroborated by its occurrance in the *Mary Rose* sample. The greater trochanter is also larger in this sample, suggesting a greater use of the other gluteal muscles.

The effects of diet on the amount of bone have been fully discussed. It is unclear whether increases in the dimensions of the 16th century group occurred as a result of a better diet aboard the ship or as a result of the secular improvement in diet for the general population which occurred between the early and late medieval periods. Neither is it clear whether the ship's crew were initially selected for their large size and robusticity or for their occupations, nor whether a long term career on the flagship with a better diet increased their dimensions.

It can be suggested that some of the present results indicate patterns of activity. It is known in general what the men from the *Mary Rose* were doing, and differences in dimensions in both the humerus and femur seem to be indicating increased levels of activity in this sample, in comparison with the Norwich sample. It is essential to emphasise that it is not possible to examine an individual archaeological skeleton and determine the occupation of that individual when alive. However, the results of the present investigation suggest that certain procedures may be able to provide some indications. Primarily, it is necessary to obtain two or more broadly contemporary groups for study. Patterns of asymmetry can then be established for the groups and correlated with size. Weak correlations will indicate differences due to factors other than size. These factors can perhaps then be related to patterns of activity. Knowledge, rather than speculation, of a group's actual activities will enhance such interpretation. However, diagnosis of a specific activity in a single individual from skeletal changes will only be possible when that individual's occupation is already known.

7.2 SUGGESTIONS FOR FURTHER WORK.

Analysis of the present results suggests several areas where further work might prove fruitful. The differences in patterns of asymmetry between the humerus and the femur are probably related to the different functions of the upper and lower limb. For example, Jolicoeur (1963) has argued that the marked bilateral asymmetry of the forelimbs in various species, including man, is "related to functions other than locomotion" (p430). A difference in patterns of asymmetry between the limbs has not been established for the early hominids. Supposing there are enough paired bones to work with, it would be useful to attempt to evaluate with which group this asymmetry begins. Thus, it might be possible to add to the present knowledge on the origins of bipedalism.

Perhaps a more obvious extension of the present work would be to include other paired bones, initially for males. The problems of commingling present in the *Mary Rose* group have made this impossible here. However, more bone pairs could be used from large, non-commingled groups. It would be useful to evaluate the radius and ulna together with the humerus, and the tibia together with the femur. The pattern of asymmetry and patterns of activity-related change could be evaluated in this way for larger areas of the skeleton. The scapula and clavicle should be measured and assessed with the proximal humerus in order to extend the work on the shoulders reported here. The scapula presents problems in archaeological material since it is often damaged. Since they are well-preserved, however, some work has already been undertaken on the scapulae from the *Mary Rose* (Stirland, 1992). This will be extended.

It would be useful to attempt to extend some of the work on the evaluation of areas of muscle insertion. The measurement of the linea aspera devised for the present research proved to be unrepeatable. Perhaps it would be possible to derive a value for this feature by using the midshaft measurements. Given the present results, it would also be of interest to devise a way in which the presence of the third trochanter could be scored with the degree of development of gluteus maximus.

A serious attempt should be made to devise a more accurate method of determining femoral torsion, particularly in the living. Such work would have valuable application to the accurate fixture of prostheses, especially in younger individuals where replacements are expected to have long lifetimes.

Finally, the comparison of the two archaeological groups has raised some interesting questions. It is not clear whether the increase in various dimensions in the *Mary Rose* group is a function of the initial selection of larger men and their subsequent patterns of activity, an improved diet on board ship or a general improvement in diet over time, particularly during the Tudor period. Comparison of paired humeri and femora from other medieval and late medieval groups of males might provide some answers to these questions. A similar analysis of paired humeri and femora from groups of females and from immature samples would indicate to what extent the observed changes are related to sex and to skeletal maturity.

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APPENDIX I: SUMMARY DESCRIPTIVE STATISTICS.

a. Humerus: whole group (top); by side (bottom).
b. Femur: whole group.
c. Femur: by side.
d. Humerus: by age on left.
e. Humerus: by age on right.
f. Humerus: by site on left.
g. Humerus: by site on right.
h. Femur: by age on left.
i. Femur: by age on right.
j. Femur: by site on left.
k. Femur: by site on right.
l. Humerus X-rays: whole group (top); by side (bottom).
m. Humerus: YA X-rays, archaeological groups & divers.
n. Humerus: YA X-rays, archaeological groups only.
o. Humerus: MA X-rays, archaeological groups only.
p. Femur: X-rays for whole group (top); YA X-rays, archaeological groups & divers (bottom).
q. Femur: YA X-rays, archaeological groups only.
r. Femur: MA X-rays, archaeological groups only.

Note: all age and site categories are the same as those used throughout the text.

a

	N	N*	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN
height	198	2	1.7204	1.7100	1.7197	0.0458	0.0033
maxL	198	2	328.29	327.00	327.95	14.75	1.05
proxB	184	16	51.059	51.100	51.014	2.391	0.176
distB	187	13	63.952	63.900	63.878	3.294	0.241
head	188	12	46.847	47.000	46.841	2.375	0.173
MSmax	194	6	23.157	23.100	23.115	1.638	0.118
MSmin	194	6	19.538	19.300	19.466	1.563	0.112
circum	196	4	69.615	69.000	69.447	4.334	0.310
HorLtub	190	10	16.058	16.050	16.071	2.075	0.151
DepLtub	184	16	8.172	8.000	8.145	1.397	0.103
Gtub	188	12	34.910	34.900	34.891	2.027	0.148
torsion	184	16	78.913	80.000	79.139	4.330	0.319
lesions	198	2	0.4242	0.0000	0.3006	0.8707	0.0619

	MIN	MAX	Q1	Q3
height	1.6300	1.8500	1.6900	1.7500
maxL	298.00	373.00	319.00	337.25
proxB	46.000	57.300	49.300	52.400
distB	57.000	73.500	61.400	66.000
head	40.800	52.500	45.000	48.275
MSmax	19.400	28.000	22.000	24.100
MSmin	16.300	24.900	18.400	20.500
circum	60.000	83.000	67.000	72.000
HorLtub	10.700	21.300	14.600	17.525
DepLtub	4.000	12.500	7.000	9.000
Gtub	29.300	41.400	33.600	36.175
torsion	65.000	87.000	77.000	82.000
lesions	0.0000	4.0000	0.0000	0.0000

	side	N	N*	MEAN	MEDIAN	TRMEAN
height	1	99	1	1.7204	1.7100	1.7197
	2	99	1	1.7204	1.7100	1.7197
maxL	1	99	1	327.13	325.00	326.67
	2	99	1	329.45	327.00	329.22
proxB	1	92	8	50.837	50.500	50.765
	2	92	8	51.280	51.300	51.257
distB	1	93	7	63.876	63.800	63.802
	2	94	6	64.028	64.000	63.950
head	1	94	6	46.597	46.700	46.580
	2	94	6	47.097	47.000	47.094
MSmax	1	97	3	22.766	22.800	22.711
	2	97	3	23.547	23.600	23.517
MSmin	1	97	3	19.337	19.100	19.267
	2	97	3	19.738	19.600	19.669
circum	1	98	2	68.844	68.250	68.684
	2	98	2	70.387	70.000	70.209
HorLtub	1	95	5	16.107	16.100	16.121
	2	95	5	16.009	16.000	16.016
DepLtub	1	92	8	8.136	8.000	8.146
	2	92	8	8.208	8.000	8.148
Gtub	1	94	6	34.426	34.300	34.442
	2	94	6	35.394	35.000	35.362
torsion	1	92	8	79.250	80.000	79.549
	2	92	8	78.576	79.000	78.768

	side	STDEV	SEMEAN	MIN	MAX	Q1	Q3
height	1	0.0459	0.0046	1.6300	1.8500	1.6900	1.7500
	2	0.0459	0.0046	1.6300	1.8500	1.6900	1.7500
maxL	1	14.93	1.50	298.00	373.00	318.00	336.00
	2	14.54	1.46	302.00	372.00	320.00	340.00
proxB	1	2.386	0.249	46.600	57.300	49.000	52.400
	2	2.389	0.249	46.000	57.000	50.000	52.475
distB	1	3.326	0.345	57.000	73.500	61.500	65.750
	2	3.279	0.338	58.000	72.500	61.350	66.400
head	1	2.467	0.254	40.800	52.300	44.800	48.025
	2	2.265	0.234	42.200	52.500	45.400	48.525
MSmax	1	1.546	0.157	19.400	27.700	21.700	23.550
	2	1.643	0.167	20.000	28.000	22.300	24.800
MSmin	1	1.493	0.152	16.300	24.900	18.300	20.050
	2	1.614	0.164	16.600	24.600	18.550	20.850
circum	1	4.291	0.433	60.000	83.000	66.000	71.625
	2	4.259	0.430	62.000	82.000	67.500	72.625
HorLtub	1	1.966	0.202	11.200	20.300	14.800	17.500
	2	2.188	0.224	10.700	21.300	14.300	17.800
DepLtub	1	1.377	0.144	4.000	12.000	7.000	9.000
	2	1.424	0.148	5.500	12.500	7.000	9.000
Gtub	1	1.850	0.191	29.300	38.700	33.100	35.525
	2	2.090	0.216	30.200	41.400	34.000	36.800
torsion	1	4.339	0.452	65.000	87.000	78.000	82.000
	2	4.318	0.450	66.000	86.000	77.000	82.000

summary stats for whole group: humerus.

b

	N	N*	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN
height	224	0	1.6984	1.7000	1.6981	0.0500	0.0033
L1	224	0	453.34	454.00	453.45	21.77	1.45
L2	222	2	450.98	451.00	450.91	21.20	1.42
APdiam	224	0	27.646	27.700	27.663	2.180	0.146
MLdiam	224	0	34.753	34.900	34.743	2.587	0.173
APpil	220	4	29.495	29.400	29.447	2.556	0.172
MLpil	220	4	28.548	28.400	28.509	1.894	0.128
APpop	220	4	30.295	30.100	30.243	2.061	0.139
MLpop	220	4	35.305	34.800	35.227	2.815	0.190
MScirc	220	4	91.895	91.500	91.820	5.807	0.391
head	212	12	48.716	48.700	48.772	2.532	0.174
Bicond	200	24	82.022	82.200	82.055	3.749	0.265
Llcond	204	20	63.106	63.100	63.100	3.098	0.217
Lmcond	204	20	63.116	62.950	63.030	3.491	0.244
Blcond	148	76	30.646	30.400	30.616	1.728	0.142
Bmcond	117	107	27.373	27.500	27.321	2.018	0.187
GreatT	182	42	46.340	46.700	46.315	3.198	0.237
LessT	218	6	18.783	18.900	18.787	1.801	0.122
chord	210	14	241.71	242.00	242.03	14.09	0.97
bow	210	14	7.305	7.000	7.298	2.156	0.149
LAH	208	16	4.483	4.000	4.354	1.881	0.130
Hdneck	222	2	82.613	82.000	82.470	6.175	0.414
Ahead	222	2	126.38	127.00	126.46	6.33	0.42

	MIN	MAX	Q1	Q3
height	1.5500	1.8300	1.6600	1.7300
L1	387.00	509.00	440.00	468.00
L2	381.00	505.00	436.75	466.00
APdiam	20.600	33.800	26.500	28.900
MLdiam	27.500	42.700	33.000	36.300
APpil	22.100	37.000	27.825	30.950
MLpil	23.700	36.000	27.200	29.900
APpop	24.900	36.700	29.000	31.575
MLpop	26.100	43.400	33.225	37.200
MScirc	78.000	110.000	88.000	96.000
head	40.100	53.400	46.900	50.950
Bicond	72.400	90.700	79.050	84.900
Llcond	55.100	72.100	60.925	65.200
Lmcond	55.300	75.700	60.600	65.500
Blcond	26.700	36.100	29.525	31.800
Bmcond	23.200	33.000	25.850	28.700
GreatT	39.200	58.600	44.075	48.625
LessT	11.500	28.700	17.775	19.925
chord	198.00	273.00	235.00	251.00
bow	2.000	13.000	6.000	9.000
LAH	1.000	10.500	3.000	5.000
Hdneck	65.000	101.000	78.000	87.000
Ahead	106.00	141.00	122.00	131.00

C

	side	N	N*	MEAN	MEDIAN	TRMEAN
L1	1	112	0	454.14	454.50	454.31
	2	112	0	452.54	453.00	452.55
L2	1	111	1	451.77	452.00	451.76
	2	111	1	450.19	451.00	450.01
APdiam	1	112	0	27.576	27.900	27.598
	2	112	0	27.716	27.650	27.732
MLdiam	1	112	0	35.009	35.100	35.006
	2	112	0	34.496	34.300	34.478
APpil	1	110	2	29.305	29.000	29.279
	2	110	2	29.685	29.600	29.608
MLpil	1	110	2	28.646	28.600	28.581
	2	110	2	28.450	28.400	28.436
APpop	1	110	2	30.361	30.250	30.336
	2	110	2	30.228	30.000	30.152
MLpop	1	110	2	35.283	34.750	35.194
	2	110	2	35.327	34.850	35.243
MScirc	1	110	2	91.809	91.250	91.735
	2	110	2	91.980	91.500	91.891
head	1	106	6	48.674	48.800	48.700
	2	106	6	48.758	48.650	48.839
Bicond	1	100	12	81.870	82.000	81.913
	2	100	12	82.174	82.400	82.197
Llcond	1	102	10	62.807	63.000	62.788
	2	102	10	63.405	63.500	63.413
Lmcond	1	102	10	63.475	63.000	63.438
	2	102	10	62.757	62.750	62.626
Blcond	1	74	38	30.572	30.200	30.505
	2	74	38	30.720	30.700	30.712
Bmcond	1	58	54	27.459	27.550	27.408
	2	59	53	27.288	27.300	27.238
GreatT	1	91	21	45.485	45.700	45.491
	2	91	21	47.195	47.100	47.201
LessT	1	109	3	18.821	19.000	18.822
	2	109	3	18.746	18.700	18.751
chord	1	105	7	242.45	244.00	242.64
	2	105	7	240.97	241.00	241.29
bow	1	105	7	7.162	7.000	7.142
	2	105	7	7.448	7.500	7.453

	side	STDEV	SEMEAN	MIN	MAX	Q1	Q3
L1	1	21.42	2.02	387.00	500.00	440.00	469.00
	2	22.18	2.10	393.00	509.00	439.25	468.00
L2	1	20.73	1.97	381.00	497.00	437.00	466.00
	2	21.72	2.06	389.00	505.00	436.00	466.00
APdiam	1	2.304	0.218	20.600	33.800	26.300	28.975
	2	2.057	0.194	22.000	33.200	26.525	28.900
MLdiam	1	2.611	0.247	27.500	42.700	33.125	36.500
	2	2.550	0.241	28.900	41.900	32.825	36.175
APpil	1	2.527	0.241	22.100	36.000	27.975	30.800
	2	2.583	0.246	23.800	37.000	27.700	31.300
MLpil	1	1.964	0.187	23.700	36.000	27.400	29.800
	2	1.824	0.174	24.100	33.300	27.175	29.925
APpop	1	2.095	0.200	24.900	36.100	28.975	31.825
	2	2.035	0.194	26.500	36.700	29.000	31.500
MLpop	1	2.750	0.262	29.000	43.100	33.375	37.200
	2	2.890	0.276	26.100	43.400	33.175	37.225
MScirc	1	5.732	0.547	78.000	107.000	88.000	95.125
	2	5.905	0.563	78.000	110.000	88.000	96.625
head	1	2.482	0.241	43.100	53.400	46.875	50.800
	2	2.592	0.252	40.100	53.400	46.950	51.025
Bicond	1	3.767	0.377	72.400	90.000	79.200	84.900
	2	3.743	0.374	73.600	90.700	79.000	84.875
Llcond	1	3.014	0.298	55.500	70.900	60.700	64.925
	2	3.166	0.314	55.100	72.100	61.000	65.900
Lmcond	1	3.388	0.335	55.300	73.400	61.075	65.775
	2	3.571	0.354	55.700	75.700	60.100	65.025
Blcond	1	1.689	0.196	26.700	36.100	29.475	31.825
	2	1.774	0.206	27.000	35.100	29.725	31.825
Bmcond	1	1.898	0.249	24.000	33.000	25.900	28.900
	2	2.143	0.279	23.200	32.700	25.600	28.500
GreatT	1	2.959	0.310	39.200	55.700	43.400	47.400
	2	3.214	0.337	39.300	58.600	45.000	49.500
LessT	1	1.989	0.191	11.500	28.700	17.750	19.900
	2	1.599	0.153	15.100	23.700	17.750	20.000
chord	1	13.61	1.33	199.00	273.00	235.00	252.00
	2	14.58	1.42	198.00	272.00	234.50	250.00
bow	1	2.120	0.207	3.000	12.000	6.000	9.000
	2	2.193	0.214	2.000	13.000	6.000	9.000

d

	C22	N	N*	MEAN	MEDIAN	TRMEAN
length	3	46	1	327.43	329.00	327.12
	4	53	0	326.87	323.00	326.23
Pbreadth	3	42	5	50.569	50.550	50.521
	4	50	3	51.062	50.500	50.941
Dbreadth	3	45	2	63.600	63.100	63.488
	4	48	5	64.135	63.850	64.059
diamhead	3	44	3	46.239	46.250	46.200
	4	50	3	46.912	46.700	46.914
Mmaximum	3	46	1	22.424	22.500	22.395
	4	51	2	23.075	23.000	22.989
Mminimum	3	46	1	19.370	19.100	19.290
	4	51	2	19.308	19.100	19.236
circ	3	47	0	68.415	68.000	68.360
	4	51	2	69.239	69.000	68.927
Hlesstub	3	43	4	16.035	16.100	16.079
	4	52	1	16.167	16.050	16.128
Dlesstub	3	41	6	7.937	7.500	7.984
	4	51	2	8.296	8.000	8.280
Gtuber	3	45	2	33.887	34.000	33.902
	4	49	4	34.920	35.000	34.887
Tor	3	43	4	78.860	80.000	79.179
	4	49	4	79.592	80.000	79.822

	C22	STDEV	SEMEAN	MIN	MAX	Q1	Q3
length	3	14.58	2.15	303.00	360.00	315.50	336.25
	4	15.36	2.11	298.00	373.00	318.50	334.00
Pbreadth	3	2.586	0.399	46.600	55.400	48.400	52.725
	4	2.205	0.312	47.300	57.300	49.375	52.400
Dbreadth	3	3.910	0.583	57.000	73.500	60.700	66.450
	4	2.683	0.387	59.100	71.400	62.800	65.700
diamhead	3	2.742	0.413	40.800	52.300	44.350	47.950
	4	2.175	0.308	42.300	52.000	45.325	48.625
Mmaximum	3	1.459	0.215	19.400	25.800	21.175	23.250
	4	1.570	0.220	20.300	27.700	21.900	23.800
Mminimum	3	1.639	0.242	16.300	24.900	18.075	20.025
	4	1.362	0.191	16.700	22.900	18.400	20.100
circ	3	4.344	0.634	60.000	78.000	65.000	71.000
	4	4.246	0.595	63.000	83.000	66.000	72.000
Hlesstub	3	2.124	0.324	11.200	20.000	14.700	17.000
	4	1.845	0.256	12.200	20.300	14.825	17.575
Dlesstub	3	1.527	0.239	4.000	10.500	7.000	9.200
	4	1.235	0.173	5.500	12.000	7.500	9.000
Gtuber	3	1.930	0.288	29.300	38.400	32.850	35.000
	4	1.641	0.234	32.100	38.700	33.550	35.850
Tor	3	4.274	0.652	67.000	84.000	77.000	82.000
	4	4.411	0.630	65.000	87.000	78.000	82.000

3 = YA
4 = MA

summary stats for humeral measures by age on left.

e

	C42	N	N*	MEAN	MEDIAN	TRMEAN
maxlen	3	46	1	329.33	330.50	329.36
	4	53	0	329.57	327.00	329.11
PB	3	42	5	50.919	50.850	50.868
	4	50	3	51.584	51.450	51.559
DB	3	46	1	64.007	64.050	63.907
	4	48	5	64.048	64.000	63.977
HD	3	44	3	46.773	47.000	46.718
	4	50	3	47.382	47.600	47.402
Midmax	3	46	1	23.378	23.550	23.336
	4	51	2	23.700	23.800	23.687
Midmin	3	46	1	19.887	20.000	19.831
	4	51	2	19.604	19.400	19.531
Cir	3	47	0	70.132	70.000	70.074
	4	51	2	70.622	70.000	70.360
HLtub	3	43	4	15.912	15.900	15.928
	4	52	1	16.090	16.150	16.076
DLtub	3	41	6	8.134	8.000	8.108
	4	51	2	8.267	8.000	8.180
Gtuberos	3	45	2	34.949	34.800	34.941
	4	49	4	35.802	35.600	35.711
Tors	3	43	4	77.744	78.000	77.872
	4	49	4	79.306	80.000	79.444

	C42	STDEV	SEMEAN	MIN	MAX	Q1	Q3
maxlen	3	14.44	2.13	303.00	357.00	315.75	342.00
	4	14.76	2.03	302.00	372.00	322.00	337.00
PB	3	2.779	0.429	46.000	57.000	48.775	52.525
	4	1.983	0.280	47.400	56.900	50.600	52.425
DB	3	3.593	0.530	58.000	72.500	60.875	66.475
	4	2.984	0.431	59.000	71.600	61.525	66.150
HD	3	2.599	0.392	42.200	52.500	44.650	48.175
	4	1.906	0.269	43.500	51.100	46.100	48.725
Midmax	3	1.505	0.222	20.600	26.800	22.225	24.500
	4	1.759	0.246	20.000	28.000	22.600	24.800
Midmin	3	1.785	0.263	17.000	24.600	18.275	21.000
	4	1.447	0.203	16.600	24.100	18.600	20.700
Cir	3	4.069	0.593	62.000	80.000	67.500	72.500
	4	4.454	0.624	63.000	82.000	67.500	73.000
HLtub	3	2.538	0.387	10.700	21.300	14.000	18.000
	4	1.871	0.259	12.200	20.300	14.550	17.650
DLtub	3	1.392	0.217	5.500	11.000	7.000	9.000
	4	1.460	0.204	6.000	12.500	7.000	9.000
Gtuberos	3	2.194	0.327	30.200	40.000	33.800	36.450
	4	1.923	0.275	31.700	41.400	34.500	36.900
Tors	3	4.696	0.716	66.000	86.000	75.000	81.000
	4	3.858	0.551	70.000	86.000	77.000	82.000

3 = YA
4 = MA

summary stats for humeral measures by age on right.

f

	C37	N	N*	MEAN	MEDIAN	TRMEAN
length	1	63	1	326.37	325.00	326.05
	2	36	0	328.47	324.50	327.50
Pbreadth	1	58	6	50.536	50.200	50.462
	2	34	2	51.350	51.300	51.240
Dbreadth	1	58	6	63.505	63.450	63.398
	2	35	1	64.491	64.000	64.403
diamhead	1	60	4	46.232	46.400	46.206
	2	34	2	47.241	47.000	47.153
Mmaximum	1	61	3	22.684	22.500	22.607
	2	36	0	22.906	23.200	22.906
Mminimum	1	61	3	19.238	19.000	19.164
	2	36	0	19.506	19.250	19.444
circ	1	62	2	68.468	68.000	68.241
	2	36	0	69.492	69.750	69.459
Hlesstub	1	60	4	16.033	16.050	16.033
	2	35	1	16.234	16.500	16.281
Dlesstub	1	57	7	8.147	8.000	8.155
	2	35	1	8.117	8.000	8.148
Gtuber	1	59	5	34.066	34.000	34.066
	2	35	1	35.031	34.900	35.045
Toi	1	57	7	79.456	80.000	79.706
	2	35	1	78.914	80.000	79.258

	C37	STDEV	SEMEAN	MIN	MAX	Q1	Q3
length	1	15.26	1.92	298.00	363.00	316.00	335.00
	2	14.46	2.41	306.00	373.00	319.00	336.00
Pbreadth	1	2.443	0.321	46.600	55.900	48.800	52.175
	2	2.226	0.382	47.900	57.300	49.450	53.000
Dbreadth	1	3.429	0.450	57.000	73.500	60.575	65.550
	2	3.097	0.523	57.000	71.500	62.400	65.900
diamhead	1	2.601	0.336	40.800	52.300	44.425	48.000
	2	2.094	0.359	43.600	52.200	45.750	48.325
Mmaximum	1	1.669	0.214	19.400	27.700	21.750	23.400
	2	1.321	0.220	20.700	25.100	21.550	24.000
Mminimum	1	1.546	0.198	16.300	24.900	18.200	20.000
	2	1.402	0.234	17.200	23.100	18.425	20.200
circ	1	4.428	0.562	60.000	83.000	65.000	71.625
	2	4.023	0.671	60.500	78.000	67.000	71.875
Hlesstub	1	2.070	0.267	11.600	20.300	14.600	17.500
	2	1.797	0.304	11.200	19.600	15.300	17.200
Dlesstub	1	1.393	0.185	4.000	12.000	7.000	9.000
	2	1.369	0.231	5.000	10.500	7.500	9.000
Gtuber	1	1.927	0.251	29.300	38.700	32.900	35.300
	2	1.556	0.263	31.700	38.400	34.200	36.100
Tor	1	4.054	0.537	65.000	87.000	78.000	82.000
	2	4.810	0.813	67.000	86.000	75.000	82.000

1 = 780N
2 = MR

. summary stats for humeral measures by site

	C57	N	N*	MEAN	MEDIAN	TRMEAN
maxlen	1	63	1	328.87	327.00	328.81
	2	36	0	330.47	327.00	329.81
PB	1	58	6	51.197	51.300	51.194
	2	34	2	51.424	51.250	51.360
DB	1	58	6	63.595	63.100	63.504
	2	36	0	64.725	65.000	64.669
HD	1	60	4	46.933	47.000	46.957
	2	34	2	47.385	47.250	47.303
Midmax	1	61	3	23.639	23.700	23.591
	2	36	0	23.392	23.400	23.472
Midmin	1	61	3	19.677	19.500	19.598
	2	36	0	19.842	19.850	19.791
Cir	1	62	2	70.571	70.000	70.373
	2	36	0	70.069	70.250	69.953
HLtub	1	60	4	15.982	16.100	15.976
	2	35	1	16.057	16.000	16.087
DLtub	1	57	7	8.009	8.000	7.912
	2	35	1	8.531	8.500	8.519
Gtuberos	1	59	5	35.144	34.900	35.094
	2	35	1	35.814	35.700	35.755
Tors	1	57	7	79.140	80.000	79.235
	2	35	1	77.657	79.000	77.871

	C57	STDEV	SEMEAN	MIN	MAX	Q1	Q3
maxlen	1	14.89	1.88	302.00	359.00	318.00	340.00
	2	14.06	2.34	305.00	372.00	321.00	340.75
PB	1	2.429	0.319	46.000	57.000	49.975	52.400
	2	2.348	0.403	46.800	56.900	50.075	52.725
DB	1	3.335	0.438	58.000	72.500	60.975	66.250
	2	3.104	0.517	58.600	71.600	62.850	66.700
HD	1	2.352	0.304	42.200	51.200	45.025	48.375
	2	2.105	0.361	43.400	52.500	45.875	48.700
Midmax	1	1.699	0.218	20.300	28.000	22.300	24.750
	2	1.553	0.259	20.000	25.800	22.175	24.800
Midmin	1	1.490	0.191	17.000	24.600	18.600	20.850
	2	1.822	0.304	16.600	24.100	18.200	20.950
Cir	1	4.324	0.549	62.000	82.000	67.875	73.000
	2	4.185	0.698	62.000	80.000	67.125	72.500
HLtub	1	2.080	0.268	11.900	20.000	14.175	17.625
	2	2.392	0.404	10.700	21.300	14.300	17.800
DLtub	1	1.441	0.191	5.500	12.500	7.000	9.000
	2	1.353	0.229	6.000	11.000	7.500	10.000
Gtuberos	1	2.237	0.291	30.200	41.400	33.900	36.300
	2	1.767	0.299	33.000	40.000	34.500	37.000
Tors	1	3.652	0.484	70.000	86.000	77.000	82.000
	2	5.150	0.871	66.000	85.000	75.000	82.000

summary stats for humeral measures by site on the right.

1 = 780N

2 = MR

h

	C42	N	N*	MEAN	MEDIAN	TRMEAN
Mlength	3	64	0	452.69	456.50	453.33
	4	48	0	456.08	453.50	455.82
Plength	3	63	1	450.78	452.00	451.25
	4	48	0	453.06	450.50	452.73
APdia	3	64	0	27.477	27.650	27.503
	4	48	0	27.708	28.000	27.689
MLdia	3	64	0	34.617	35.000	34.678
	4	48	0	35.531	35.450	35.409
APpilas	3	63	1	29.083	28.700	28.993
	4	47	1	29.604	29.900	29.670
MLpilas	3	63	1	28.238	28.200	28.221
	4	47	1	29.194	29.000	29.109
APpoplit	3	63	1	30.132	30.000	30.146
	4	47	1	30.668	30.600	30.607
Mlpoplit	3	63	1	34.827	34.300	34.754
	4	47	1	35.894	35.400	35.830
circum	3	63	1	90.881	90.000	90.763
	4	47	1	93.053	94.000	93.081
diamhead	3	60	4	48.125	48.150	48.115
	4	46	2	49.389	49.250	49.402
bicondyl	3	57	7	81.300	81.700	81.363
	4	43	5	82.626	82.600	82.674
llatcond	3	55	9	62.438	63.000	62.514
	4	47	1	63.238	63.000	63.119
lmedcond	3	56	8	63.154	62.650	63.128
	4	46	2	63.867	63.950	63.824
blatcond	3	40	24	30.190	30.000	30.175
	4	34	14	31.021	31.100	30.950
bmedcond	3	30	34	27.307	27.150	27.169
	4	28	20	27.621	27.800	27.646
Gtroch	3	52	12	44.969	45.000	45.011
	4	39	9	46.172	46.300	46.137
Ltroch	3	64	0	18.853	19.000	18.722
	4	45	3	18.776	19.100	18.963
Bchord	3	58	6	242.91	244.50	243.21
	4	47	1	241.87	242.00	241.93
subtense	3	58	6	7.431	8.000	7.433
	4	47	1	6.830	6.500	6.791

	C42	STDEV	SEMEAN	MIN	MAX	Q1	Q3
Mlength	3	21.85	2.73	387.00	498.00	435.25	469.75
	4	20.90	3.02	418.00	500.00	440.50	468.75
Plength	3	20.98	2.64	381.00	497.00	433.00	466.00
	4	20.55	2.97	417.00	497.00	439.25	466.75
APdia	3	2.294	0.287	20.600	32.900	26.025	28.975
	4	2.334	0.337	22.700	33.800	26.700	28.975
MLdia	3	2.677	0.335	27.500	41.000	32.750	36.075
	4	2.451	0.354	30.900	42.700	33.650	36.725
APpilas	3	2.288	0.288	24.500	36.000	28.000	30.600
	4	2.814	0.410	22.100	35.500	27.800	31.200
MLpilas	3	1.810	0.228	23.700	33.000	27.000	29.200
	4	2.047	0.299	25.000	36.000	27.700	30.000
APpoplit	3	2.007	0.253	24.900	34.300	28.900	31.400
	4	2.191	0.320	26.100	36.100	29.400	32.000
Mlpoplit	3	2.586	0.326	29.000	41.600	33.100	36.600
	4	2.871	0.419	31.000	43.100	33.800	38.100
circum	3	5.336	0.672	79.000	104.000	87.000	94.000
	4	6.060	0.884	78.000	107.000	88.000	96.000
diamhead	3	2.536	0.327	43.100	53.400	46.000	49.975
	4	2.239	0.330	45.500	53.000	47.675	51.150
bicondyl	3	3.878	0.514	72.400	90.000	78.600	84.900
	4	3.517	0.536	75.100	89.400	80.100	85.000
llatcond	3	3.068	0.414	55.500	68.000	60.100	65.000
	4	2.923	0.426	57.900	70.900	61.400	64.600
lmedcond	3	3.270	0.437	56.100	70.200	60.725	65.675
	4	3.523	0.519	55.300	73.400	61.400	66.225
blatcond	3	1.366	0.216	27.800	32.900	29.075	31.025
	4	1.929	0.331	26.700	36.100	29.750	32.100
bmedcond	3	2.095	0.383	24.200	33.000	25.900	29.000
	4	1.684	0.318	24.000	30.600	26.500	28.875
Gtroch	3	2.657	0.368	39.500	50.000	42.900	47.175
	4	3.228	0.517	39.200	55.700	43.800	48.500
Ltroch	3	2.020	0.252	15.200	28.700	17.600	19.875
	4	1.966	0.293	11.500	22.100	18.050	19.950
Bchord	3	13.57	1.78	199.00	270.00	235.00	253.25
	4	13.78	2.01	202.00	273.00	235.00	250.00
subtense	3	2.163	0.284	3.000	12.000	5.875	9.000
	4	2.038	0.297	3.000	12.000	6.000	8.000

	C42	N	N*	MEAN	MEDIAN	TRMEAN
Mlength	3	64	0	451.14	453.00	451.41
	4	48	0	454.42	453.00	454.07
Plength	3	63	1	449.13	450.00	449.30
	4	48	0	451.58	451.50	451.18
APdia	3	64	0	27.573	27.500	27.598
	4	48	0	27.906	27.850	27.900
MLdia	3	64	0	34.181	34.050	34.197
	4	48	0	34.917	34.850	34.793
APpilas	3	63	1	29.359	29.200	29.230
	4	47	1	30.123	30.100	30.142
MLpilas	3	63	1	28.105	28.000	28.091
	4	47	1	28.913	28.900	28.886
APpoplit	3	63	1	29.967	29.700	29.935
	4	47	1	30.579	30.300	30.484
MLpoplit	3	63	1	34.844	34.300	34.825
	4	47	1	35.974	35.800	35.893
circum	3	63	1	90.992	90.500	90.754
	4	47	1	93.304	94.000	93.426
diamhead	3	60	4	48.285	48.100	48.385
	4	46	2	49.374	49.350	49.381
bicondyl	3	57	7	81.556	82.000	81.625
	4	43	5	82.993	82.700	82.938
llatcond	3	55	9	62.796	62.900	62.880
	4	47	1	64.117	63.700	64.023
lmedcond	3	56	8	62.236	62.200	62.176
	4	46	2	63.391	63.200	63.150
blatcond	3	40	24	30.415	30.000	30.403
	4	34	14	31.079	30.850	31.100
bmedcond	3	30	34	26.873	25.850	26.731
	4	29	19	27.717	27.700	27.733
Gtroch	3	52	12	46.762	47.000	46.809
	4	39	9	47.772	47.900	47.626
Ltroch	3	64	0	18.656	18.700	18.698
	4	45	3	18.873	18.700	18.849
Bchord	3	58	6	240.41	241.00	240.88
	4	47	1	241.66	242.00	241.67
subtense	3	58	6	7.681	8.000	7.692
	4	47	1	7.160	7.000	7.198

	C42	STDEV	SEMEAN	MIN	MAX	Q1	Q3
Mlength	3	22.64	2.83	393.00	509.00	436.25	467.00
	4	21.65	3.12	418.00	499.00	440.25	471.50
Plength	3	21.77	2.74	389.00	505.00	434.00	466.00
	4	21.81	3.15	414.00	498.00	438.25	468.75
APdia	3	2.177	0.272	22.000	32.000	26.225	29.000
	4	1.889	0.273	22.700	33.200	26.900	28.875
MLdia	3	2.603	0.325	28.900	39.400	32.625	36.150
	4	2.440	0.352	30.500	41.900	33.050	36.325
APpilas	3	2.514	0.317	25.200	37.000	27.200	30.800
	4	2.636	0.385	23.800	35.600	28.500	31.800
MLpilas	3	1.827	0.230	24.100	32.700	26.900	29.700
	4	1.733	0.253	25.100	33.300	27.400	30.000
APpoplit	3	1.916	0.241	26.500	35.000	28.800	31.300
	4	2.156	0.314	26.600	36.700	29.100	31.700
MLpoplit	3	2.654	0.334	26.100	41.200	33.000	36.400
	4	3.091	0.451	30.600	43.400	33.300	38.200
circum	3	5.942	0.749	80.000	110.000	86.000	95.000
	4	5.649	0.824	78.000	105.000	89.000	97.000
diamhead	3	2.722	0.351	40.100	52.700	46.625	50.950
	4	2.297	0.339	45.100	53.400	47.675	51.450
bicondyl	3	3.977	0.527	73.600	89.000	78.450	85.100
	4	3.276	0.500	76.200	90.700	80.800	84.900
llatcond	3	3.106	0.419	55.100	68.100	60.500	65.900
	4	3.119	0.455	58.700	72.100	62.100	66.100
lmedcond	3	3.588	0.480	55.700	71.200	58.650	65.000
	4	3.483	0.514	58.300	75.700	60.525	65.275
blatcond	3	1.707	0.270	27.000	34.000	29.150	31.625
	4	1.809	0.310	27.100	35.100	30.150	32.225
bmedcond	3	2.430	0.444	23.200	32.700	25.075	28.125
	4	1.738	0.323	24.200	30.800	26.550	28.950
Gtroch	3	3.273	0.454	39.300	54.000	44.850	49.100
	4	3.080	0.493	42.800	58.600	45.300	49.800
Ltroch	3	1.583	0.198	15.100	21.100	17.425	20.000
	4	1.631	0.243	15.400	23.700	17.850	19.750
Bchord	3	15.90	2.09	198.00	270.00	233.50	250.25
	4	12.91	1.88	210.00	272.00	235.00	249.00
subtense	3	2.373	0.312	2.000	13.000	6.375	9.000
	4	1.934	0.282	2.000	11.500	6.000	8.000

	C64	N	N*	MEAN	MEDIAN	TRMEAN
Mlength	1	57	0	449.09	450.00	449.37
	2	55	0	459.38	458.00	459.31
Plength	1	56	1	446.80	448.00	446.88
	2	55	0	456.82	456.00	456.65
APdia	1	57	0	27.228	27.100	27.253
	2	55	0	27.936	28.200	27.951
MLdia	1	57	0	34.863	34.900	34.771
	2	55	0	35.160	35.500	35.259
APpilas	1	55	2	29.169	29.000	29.094
	2	55	0	29.442	29.000	29.459
MLpilas	1	55	2	28.535	28.400	28.488
	2	55	0	28.758	28.800	28.661
APpoplit	1	56	1	30.350	30.250	30.288
	2	54	1	30.372	30.200	30.396
Mlpoplit	1	56	1	34.639	34.100	34.484
	2	54	1	35.950	35.500	35.910
circum	1	55	2	91.427	91.000	91.459
	2	55	0	92.191	91.500	92.010
diamhead	1	51	6	48.567	48.700	48.553
	2	55	0	48.773	48.800	48.847
bicondyl	1	50	7	80.914	80.500	80.839
	2	50	5	82.826	82.500	82.866
llatcond	1	51	6	62.273	61.700	62.138
	2	51	4	63.341	63.200	63.402
lmedcond	1	52	5	62.762	62.400	62.654
	2	50	5	64.218	64.200	64.186
blatcond	1	32	25	30.131	29.950	29.914
	2	42	13	30.907	30.800	30.926
bmedcond	1	24	33	27.358	27.400	27.305
	2	34	21	27.529	27.600	27.473
Gtroch	1	39	18	44.605	44.300	44.606
	2	52	3	46.144	46.500	46.124
Ltroch	1	55	2	18.565	18.800	18.506
	2	54	1	19.081	19.100	19.158
Bchord	1	50	7	237.62	238.50	237.98
	2	55	0	246.84	248.00	247.33
subtense	1	50	7	6.740	6.500	6.705
	2	55	0	7.545	8.000	7.551

	C64	STDEV	SEMEAN	MIN	MAX	Q1	Q3
Mlength	1	22.05	2.92	387.00	497.00	434.50	465.00
	2	19.60	2.64	418.00	500.00	445.00	475.00
Plength	1	21.10	2.82	381.00	493.00	433.00	461.25
	2	19.25	2.60	417.00	497.00	442.00	471.00
APdia	1	2.389	0.316	20.600	32.600	25.800	28.850
	2	2.174	0.293	22.700	33.800	26.900	29.100
MLdia	1	2.696	0.357	27.500	42.700	33.150	36.200
	2	2.536	0.342	28.400	40.900	33.100	37.000
APpilas	1	2.683	0.362	23.300	35.500	27.200	30.800
	2	2.377	0.321	22.100	36.000	28.000	30.800
MLpilas	1	2.051	0.277	23.700	36.000	27.600	29.600
	2	1.885	0.254	25.800	33.300	27.400	29.900
APpoplit	1	2.281	0.305	24.900	36.100	28.700	31.475
	2	1.904	0.259	26.100	34.000	28.975	32.025
Mlpoplit	1	2.875	0.384	29.000	43.100	32.600	36.150
	2	2.467	0.336	31.000	41.600	33.975	37.450
circum	1	5.945	0.802	78.000	103.000	87.000	95.000
	2	5.540	0.747	82.000	107.000	88.000	95.500
diamhead	1	2.650	0.371	44.000	53.400	46.000	50.700
	2	2.336	0.315	43.100	52.800	47.100	51.000
bicondyl	1	3.989	0.564	74.100	89.400	77.450	84.200
	2	3.300	0.467	72.400	90.000	80.425	85.150
llatcond	1	3.282	0.460	55.500	70.900	60.000	64.400
	2	2.644	0.370	55.500	68.700	62.400	65.000
lmedcond	1	3.625	0.503	55.300	73.400	60.225	65.450
	2	2.979	0.421	57.900	70.800	62.200	66.475
blatcond	1	1.834	0.324	27.800	36.100	28.725	31.250
	2	1.506	0.232	26.700	33.800	29.900	32.100
bmedcond	1	1.575	0.321	24.600	31.300	26.075	28.100
	2	2.117	0.363	24.000	33.000	25.900	29.000
Gtroch	1	2.943	0.471	39.200	50.500	42.500	46.900
	2	2.822	0.391	40.500	55.700	44.025	48.100
Ltroch	1	2.169	0.292	12.200	28.700	17.200	19.500
	2	1.770	0.241	11.500	23.000	18.200	20.000
Bchord	1	12.14	1.72	199.00	258.00	229.50	247.25
	2	13.49	1.82	202.00	273.00	238.00	255.00
subtense	1	1.996	0.282	3.000	11.000	5.000	8.000
	2	2.174	0.293	3.000	12.000	6.000	9.000

k

	C64	N	N*	MEAN	MEDIAN	TRMEAN
Mlength	1	57	0	447.95	451.00	448.24
	2	55	0	457.31	457.00	456.98
Plength	1	56	1	445.66	449.00	445.68
	2	55	0	454.80	454.00	454.47
APdia	1	57	0	27.251	27.300	27.227
	2	55	0	28.198	27.900	28.243
MLdia	1	57	0	34.218	33.900	34.178
	2	55	0	34.785	34.900	34.786
APpilas	1	55	2	29.458	29.200	29.406
	2	55	0	29.913	29.900	29.769
MLpilas	1	55	2	28.349	28.400	28.351
	2	55	0	28.551	28.400	28.504
APpoplit	1	56	1	30.305	30.050	30.188
	2	54	1	30.148	29.950	30.117
MLpoplit	1	56	1	34.655	34.250	34.556
	2	54	1	36.024	36.050	35.950
circum	1	55	2	91.627	90.500	91.724
	2	55	0	92.333	91.500	92.057
diamhead	1	51	6	48.506	48.200	48.598
	2	55	0	48.991	48.900	49.073
bicondyl	1	50	7	81.362	80.900	81.311
	2	50	5	82.986	82.900	83.014
llatcond	1	51	6	62.916	62.200	62.809
	2	51	4	63.894	64.100	63.998
lmedcond	1	52	5	62.188	61.600	61.963
	2	50	5	63.348	63.650	63.245
blatcond	1	32	25	30.291	30.100	30.236
	2	42	13	31.048	30.850	31.005
bmedcond	1	24	33	26.913	27.000	26.836
	2	35	20	27.546	27.700	27.516
Gtroch	1	39	18	46.254	46.100	46.320
	2	52	3	47.900	47.750	47.857
Ltroch	1	55	2	18.564	18.500	18.590
	2	54	1	18.931	19.150	18.923
Bchord	1	50	7	236.16	238.00	236.73
	2	55	0	245.35	244.00	245.57
subtense	1	50	7	6.900	7.000	6.920
	2	55	0	7.945	8.000	7.980

	C64	STDEV	SEMEAN	MIN	MAX	Q1	Q3
Mlength	1	22.92	3.04	393.00	496.00	432.00	464.00
	2	20.52	2.77	415.00	509.00	442.00	473.00
Plength	1	22.02	2.94	389.00	494.00	428.50	460.00
	2	20.60	2.78	410.00	505.00	440.00	469.00
APdia	1	2.008	0.266	22.700	33.200	26.200	28.500
	2	2.012	0.271	22.000	32.100	27.100	29.600
MLdia	1	2.679	0.355	28.900	41.900	32.750	35.650
	2	2.398	0.323	29.300	41.400	32.800	36.500
APpilas	1	2.774	0.374	23.800	35.600	27.200	31.600
	2	2.380	0.321	25.400	37.000	28.100	30.800
MLpilas	1	1.823	0.246	24.100	33.300	27.200	29.900
	2	1.836	0.248	25.200	32.700	27.000	30.000
APpoplit	1	2.243	0.300	26.500	36.700	28.850	31.450
	2	1.812	0.247	26.600	35.000	29.000	31.525
MLpoplit	1	2.962	0.396	26.100	43.400	32.575	36.075
	2	2.665	0.363	31.100	42.100	33.850	37.900
circum	1	5.915	0.798	78.000	103.000	87.000	96.000
	2	5.928	0.799	82.000	110.000	88.000	97.000
diamhead	1	2.698	0.378	40.100	53.400	46.700	50.500
	2	2.492	0.336	43.600	52.900	47.000	51.700
bicondyl	1	4.036	0.571	73.600	89.900	78.075	84.350
	2	3.266	0.462	73.600	90.700	81.075	85.425
llatcond	1	3.522	0.493	55.100	72.100	60.500	65.200
	2	2.713	0.380	57.100	68.100	62.000	66.000
lmedcond	1	3.981	0.552	55.700	75.700	59.000	64.100
	2	3.015	0.426	57.800	71.200	60.750	65.225
blatcond	1	2.079	0.367	27.000	35.100	29.000	31.750
	2	1.442	0.223	28.600	34.100	29.975	31.850
bmedcond	1	1.881	0.384	24.200	31.300	25.350	28.000
	2	2.296	0.388	23.200	32.700	25.700	29.700
Gtroch	1	3.109	0.498	39.300	51.400	43.700	48.800
	2	3.137	0.435	40.900	58.600	45.700	49.875
Ltroch	1	1.586	0.214	15.100	22.000	17.600	19.900
	2	1.606	0.219	15.400	23.700	17.850	20.000
Bchord	1	14.59	2.06	198.00	265.00	228.50	247.00
	2	13.25	1.79	215.00	272.00	238.00	253.00
subtense	1	2.028	0.287	2.000	11.500	5.000	8.000
	2	2.235	0.301	2.000	13.000	7.000	9.000

	L/R	N	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN
TOTAL	1	127	25.889	25.900	25.850	2.431	0.216
	2	127	26.481	26.400	26.452	2.423	0.215
MED.	1	127	16.896	17.000	16.784	2.585	0.229
	2	127	17.646	17.500	17.599	2.482	0.220
CORTEX	1	127	8.996	8.900	8.971	1.669	0.148
	2	127	8.835	8.700	8.785	1.687	0.150
C.AREA	1	127	301.50	292.00	299.83	62.56	5.55
	2	127	305.25	301.00	303.52	65.31	5.80
PER.C	1	127	34.951	34.800	34.992	6.255	0.555
	2	127	33.657	33.300	33.439	6.297	0.559

	L/R	MIN	MAX	Q1	Q3
TOTAL	1	21.300	33.000	24.200	27.000
	2	20.800	33.000	24.400	28.000
MED.	1	12.000	24.000	14.900	18.000
	2	12.800	24.000	15.700	19.800
CORTEX	1	4.900	14.000	8.000	10.000
	2	5.600	14.000	7.700	10.000
C.AREA	1	163.00	506.00	259.00	345.00
	2	173.00	484.00	255.00	351.00
PER.C	1	20.000	51.800	30.800	38.500
	2	21.400	53.000	28.700	37.600

L

	N	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN
tot	95	26.235	26.000	26.214	2.510	0.258
medul	95	17.014	17.000	16.882	2.641	0.271
cort	95	9.223	9.000	9.212	1.747	0.179
cort.a	95	312.63	309.00	311.87	65.88	6.76
per.cor	95	35.367	35.300	35.441	6.373	0.654

	MIN	MAX	Q1	Q3
tot	21.300	33.000	24.300	28.000
medul	12.000	24.000	15.000	18.600
cort	4.900	14.000	8.000	10.100
cort.a	163.00	506.00	267.00	350.00
per.cor	20.000	51.800	31.000	39.200

R

	N	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN
tot.all	95	26.813	27.000	26.815	2.531	0.260
medull	95	17.725	17.600	17.682	2.611	0.268
cort.w	95	9.087	9.000	9.047	1.757	0.180
cortarea	95	316.62	327.00	315.76	68.09	6.99
%cortex	95	34.269	33.400	34.060	6.578	0.675

	MIN	MAX	Q1	Q3
tot.all	20.800	33.000	24.800	28.000
medull	12.800	24.000	15.700	20.000
cort.w	5.600	14.000	8.000	10.000
cortarea	173.00	484.00	259.00	361.00
%cortex	21.400	53.000	29.600	38.700

m

	num	N	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN
tot	1	46	24.550	24.350	24.529	1.861	0.274
	2	49	27.816	27.000	27.778	1.954	0.279
medul	1	46	15.746	15.500	15.695	1.815	0.268
	2	49	18.204	18.000	18.178	2.754	0.393
cort	1	46	8.809	8.850	8.824	1.504	0.222
	2	49	9.612	10.000	9.578	1.880	0.269
cort.a	1	46	278.78	273.00	278.38	53.70	7.92
	2	49	344.41	345.00	343.47	60.56	8.65
per.cor	1	46	35.852	36.150	35.981	5.528	0.815
	2	49	34.91	34.60	34.88	7.10	1.01

	num	MIN	MAX	Q1	Q3
tot	1	21.300	28.500	23.375	26.000
	2	24.000	33.000	26.000	29.000
medul	1	12.000	20.000	14.400	17.000
	2	13.000	24.000	17.000	20.000
cort	1	4.900	12.400	7.975	9.925
	2	6.000	14.000	8.000	11.000
cort.a	1	163.00	405.00	247.75	321.00
	2	226.00	506.00	294.00	377.00
per.cor	1	20.800	45.900	32.475	39.375
	2	20.00	51.80	30.80	38.95

summary stats for YA xray on left.

	pin.no	N	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN
tot.all	1	46	25.330	25.400	25.312	2.099	0.310
	2	49	28.204	28.000	28.244	2.081	0.297
medull	1	46	16.476	16.400	16.455	2.029	0.299
	2	49	18.898	19.000	18.911	2.568	0.367
cort.w	1	46	8.854	8.600	8.810	1.771	0.261
	2	49	9.306	9.000	9.289	1.735	0.248
cortarea	1	46	290.96	277.50	290.21	63.75	9.40
	2	49	340.71	339.00	339.96	63.60	9.09
%cortex	1	46	35.302	34.500	35.055	6.721	0.991
	2	49	33.300	32.200	33.211	6.356	0.908

	pin.no	MIN	MAX	Q1	Q3
tot.all	1	20.800	30.400	23.775	26.950
	2	22.000	33.000	27.000	29.500
medull	1	12.800	20.500	14.675	17.775
	2	14.000	24.000	17.000	21.000
cort.w	1	5.600	13.100	7.575	9.925
	2	6.000	14.000	8.000	11.000
cortarea	1	173.00	431.00	245.50	342.25
	2	217.00	484.00	296.00	391.00
%cortex	1	24.900	53.000	29.775	39.350
	2	21.400	48.300	28.600	38.200

summary stats for YA xray on right; 1=archs., 2=divers.

n

	num	N	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN
tot	1	31	24.226	24.200	24.200	1.722	0.309
	3	15	25.220	25.300	25.215	2.017	0.521
medul	1	31	15.465	15.400	15.400	1.548	0.278
	3	15	16.327	16.300	16.377	2.218	0.573
cort	1	31	8.761	8.800	8.796	1.581	0.284
	3	15	8.907	8.900	8.923	1.379	0.356
cort.a	1	31	273.3	271.0	272.6	55.7	10.0
	3	15	290.1	293.0	289.2	49.1	12.7
per.cor	1	31	36.077	36.800	36.274	5.523	0.992
	3	15	35.39	35.30	35.35	5.70	1.47

	num	MIN	MAX	Q1	Q3
tot	1	21.300	27.800	23.000	25.900
	3	22.000	28.500	23.400	26.900
medul	1	13.100	18.700	14.400	16.700
	3	12.000	20.000	15.000	17.400
cort	1	4.900	12.400	7.900	9.900
	3	6.200	11.400	8.000	10.100
cort.a	1	163.0	405.0	238.0	309.0
	3	198.0	394.0	260.0	326.0
per.cor	1	20.800	45.900	33.300	39.200
	3	25.40	45.90	30.80	39.90

summary stats for the left.

	pin.no	N	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN
tot.all	1	31	24.977	24.500	24.930	2.118	0.380
	3	15	26.060	25.900	26.054	1.925	0.497
medull	1	31	16.435	16.400	16.385	1.878	0.337
	3	15	16.560	16.200	16.546	2.380	0.614
cort.w	1	31	8.542	8.300	8.504	1.502	0 270
	3	15	9.500	8.900	9.454	2.141	0.553
cortarea	1	31	278.5	273.0	277.0	58.7	10.5
	3	15	316.7	331.0	316.5	67.9	17.5
%cortex	1	31	34.76	34.60	34.32	6.21	1.11
	3	15	36.43	34.40	36.35	7.78	2.01

	pin.no	MIN	MAX	Q1	Q3
tot.all	1	20.800	30.400	23.300	26.500
	3	23.300	28.900	23.900	27.700
medull	1	13.100	20.400	14.700	17.700
	3	12.800	20.500	14.600	18.300
cort.w	1	5.600	12.400	7.500	9.800
	3	6.500	13.100	7.700	11.400
cortarea	1	173.0	399.0	244.0	338.0
	3	205.0	431.0	272.0	372.0
%cortex	1	24.90	53.00	29.70	38.10
	3	26.00	47.80	29.80	45.70

1 = 780N
3 = MR

summary stats for the right.

O

L

	num	N	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN
tot	4	32	24.862	25.200	24.818	1.860	0.329
	5	20	24.925	25.200	24.922	1.350	0.302
medul	4	32	16.547	16.400	16.479	2.418	0.427
	5	20	15.735	15.850	15.778	1.656	0.370
cort	4	32	8.322	8.350	8.307	1.199	0.212
	5	20	9.190	9.250	9.144	1.575	0.352
cort.a	4	32	268.47	275.00	267.04	35.20	6.22
	5	20	305.0	305.0	304.3	59.2	13.2
per.cor	4	32	33.72	34.60	33.75	5.81	1.03
	5	20	36.85	35.75	36.77	5.98	1.34

	num	MIN	MAX	Q1	Q3
tot	4	21.300	29.500	23.300	25.875
	5	22.700	27.200	23.500	25.925
medul	4	12.200	22.100	14.400	17.875
	5	12.200	18.500	15.050	16.775
cort	4	5.600	11.400	7.700	8.800
	5	6.200	13.000	8.550	10.275
cort.a	4	206.00	353.00	242.75	290.75
	5	208.0	414.0	281.2	341.8
per.cor	4	21.40	45.20	29.95	38.05
	5	25.10	50.00	33.03	40.95

R

	pin.no	N	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN
tot.all	4	32	25.497	25.550	25.439	1.762	0.312
	5	20	25.560	25.750	25.550	1.618	0.362
medull	4	32	17.409	17.300	17.350	2.072	0.366
	5	20	16.570	16.750	16.578	2.160	0.483
cort.w	4	32	8.087	8.150	8.093	1.194	0.211
	5	20	8.990	8.700	8.967	1.748	0.391
cortarea	4	32	271.50	265.00	269.86	41.30	7.30
	5	20	304.8	293.0	301.6	65.8	14.7
%cortex	4	32	31.837	32.800	31.854	5.043	0.891
	5	20	35.22	33.75	35.16	6.81	1.52

	pin.no	MIN	MAX	Q1	Q3
tot.all	4	22.200	29.900	24.000	26.275
	5	22.700	28.600	24.375	27.000
medull	4	14.000	22.200	15.750	19.150
	5	13.200	19.800	14.550	18.300
cort.w	4	5.800	10.100	7.175	8.875
	5	5.500	12.900	7.800	9.625
cortarea	4	199.00	361.00	233.50	304.00
	5	182.0	486.0	267.7	337.8
%cortex	4	23.400	40.400	27.950	35.950
	5	23.10	48.60	30.60	39.78

4 = 780N
5 = MR

P

	LI/RI	N	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN
TOT.C	1	137	30.428	30.100	30.429	2.671	0.228
	2	137	30.493	30.600	30.476	2.749	0.235
MED.W	1	137	14.295	14.000	14.267	2.153	0.184
	2	137	14.250	14.300	14.238	2.151	0.184
COR.	1	137	16.147	16.000	16.093	2.059	0.176
	2	137	16.243	16.000	16.151	2.073	0.177
COR.AR	1	137	568.38	554.00	564.88	102.66	8.77
	2	137	573.42	563.00	569.27	105.29	9.00
C%	1	137	53.117	53.200	53.067	5.416	0.463
	2	137	53.307	53.300	53.241	5.216	0.446

	LI/RI	MIN	MAX	Q1	Q3
TOT.C	1	23.000	36.000	28.750	32.000
	2	23.100	38.000	28.600	32.100
MED.W	1	9.000	22.000	13.000	15.600
	2	9.000	22.000	12.850	15.250
COR.	1	11.800	21.000	14.600	17.400
	2	12.400	23.100	14.900	17.650
COR.AR	1	317.00	818.00	492.00	627.00
	2	379.00	883.00	485.00	644.00
C%	1	38.900	66.700	49.750	56.200
	2	41.900	67.000	49.650	56.350

L

	N	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN
tot	113	30.388	30.100	30.366	2.601	0.245
medul	113	14.288	14.100	14.268	2.104	0.198
cort	113	16.118	16.000	16.050	2.050	0.193
cor.a	113	566.57	553.00	561.63	101.48	9.55
per.cor	113	53.085	53.200	53.053	5.429	0.511

	MIN	MAX	Q1	Q3
tot	24.900	36 000	28.650	32.000
medul	9.000	22.000	13.150	15.600
cort	12.800	21.000	14.450	17.300
cor.a	396.00	818.00	485.50	627.00
per.cor	38.900	66.700	49.800	56.200

R

	N	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN
tot.all	113	30.419	30.500	30.372	2.653	0.250
medull	113	14.254	14.300	14.241	2.149	0.202
cort.w	113	16.165	16.000	16.061	2.040	0.192
cortic.a	113	568.74	555 00	563.42	103.24	9.71
%cortex	113	53.187	53.100	53.118	5.286	0.497

	MIN	MAX	Q1	Q3
tot.all	24.000	38.000	28.500	32.000
medull	9.000	22.000	12.950	15.050
cort.w	12.400	23.100	14.900	17.350
cortic.a	379.00	883.00	485 00	631.00
%cortex	41.900	67.000	49.650	56.200

q

L

	num	N	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN
tot	1	31	29.155	29.500	29.093	2.527	0.454
	3	32	30.409	30.350	30.371	2.161	0.382
medul	1	31	13.126	13.400	13.200	2.001	0.359
	3	32	13.991	13.950	13.979	1.539	0.272
cort	1	31	16.029	15.800	15.900	1.675	0.301
	3	32	16.419	16 500	16.379	2.267	0.401
cor.a	1	31	535.6	534.0	530.3	89.7	16.1
	3	32	570.9	561.5	566.9	98.6	17.4
per.cor	1	31	55.071	54 000	54.911	4.771	0.857
	3	32	53.875	53.600	53.868	5.201	0.919

	num	MIN	MAX	Q1	Q3
tot	1	24.900	35.300	27.100	31.100
	3	26.800	34.700	28.650	31.850
medul	1	9.000	16.000	11.300	14.400
	3	10.900	17.400	13.000	14.975
cort	1	13.600	21.000	14.800	16.800
	3	12.800	20.600	14.900	18.150
cor.a	1	405.0	818.0	481.0	592.0
	3	425.0	774.0	485.0	625.7
per.cor	1	45.900	65.100	51.900	57.900
	3	44.300	63.800	49.925	58.400

R

	pin.no	N	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN
tot.all	1	31	29.068	28.800	28.952	2.498	0.449
	3	32	30.322	30.100	30.157	2.203	0.389
medull	1	31	12.974	13.300	13.067	1.818	0.327
	3	32	13.953	14.200	13.936	1.511	0.267
cort.w	1	31	16.094	15.900	16.044	1.698	0.305
	3	32	16.369	16.150	16.164	2.437	0.431
cortic.a	1	31	533.4	521.0	527.0	92.6	16.6
	3	32	570.8	553.0	559.6	107.6	19.0
%cortex	1	31	55.410	54.500	55.200	4.463	0.802
	3	32	53.825	53.600	53.661	5.318	0.940

	pin.no	MIN	MAX	Q1	Q3
tot.all	1	25.500	34.200	27.100	31.000
	3	27.000	35.900	28.625	31.700
medull	1	9.000	15.500	11.700	14.800
	3	10.400	17.500	12.850	14.875
cort.w	1	12.400	20.500	15 100	17.600
	3	13.100	23.100	14.800	17.375
cortic.a	1	379.0	771.0	460.0	583.0
	3	425.0	883.0	494.8	613.7
%cortex	1	48.200	67.000	51.900	58.300
	3	44.200	64.800	50.000	57.375

1 = 780N
3 = MR

r

L

	num	N	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN
tot	4	24	30.612	30.400	30.727	3.033	0.619
	5	23	30.109	30.300	30.090	1.996	0.416
medul	4	24	14.325	13.850	14.259	2.420	0.494
	5	23	14.109	14.000	14.143	1.864	0.389
cort	4	24	16.288	16.550	16.286	2.140	0.437
	5	23	16.000	15.800	15.933	1.690	0.352
cor.a	4	24	576.9	571.5	580.5	109.9	22.4
	5	23	555.8	572.0	556.4	74.6	15.5
per.cor	4	24	53.27	53.30	53.13	5.47	1.12
	5	23	53.17	52.40	52.77	4.87	1.01

	num	MIN	MAX	Q1	Q3
tot	4	23.000	35.700	28.800	33.000
	5	26.700	33.900	29.000	31.000
medul	4	10.200	19.900	12.600	16.300
	5	9.700	17.800	13.100	15.400
cort	4	11.800	20.800	14.625	17.575
	5	12.800	20.600	14.800	17.200
cor.a	4	317.0	757.0	514.2	659.0
	5	408.0	691.0	491.0	604.0
per.cor	4	44.20	65.30	49.70	56.97
	5	46.70	68.00	50.00	56.30

R

	pin.no	N	MEAN	MEDIAN	TRMEAN	STDEV	SEMEAN
tot.all	4	24	30.837	31.000	30.973	3.204	0.654
	5	23	30.209	30.200	30.186	2.019	0.421
medull	4	24	14.229	14.300	14.259	2.204	0.450
	5	23	14.200	13.800	14.181	2.102	0.438
cort.w	4	24	16.608	17.000	16.582	2.231	0.455
	5	23	16.022	16.000	15.976	1.920	0.400
cortic.a	4	24	595.4	589.5	595.6	114.2	23.3
	5	23	564.0	563.0	563.1	80.5	16.8
%cortex	4	24	53.88	53.50	53.74	4.94	1.01
	5	23	53.07	53.70	52.90	5.73	1.20

	pin.no	MIN	MAX	Q1	Q3
tot.all	4	23.100	35.600	28.925	33.475
	5	26.100	34.800	29.300	31.000
medull	4	10.500	17.300	12.200	16.400
	5	9.900	18.900	12.800	15.500
cort.w	4	12.600	21.200	14.900	18.175
	5	12.800	20.200	14.600	17.500
cortic.a	4	422.0	764.0	480.7	690.0
	5	420.0	726.0	490.0	632.0
%cortex	4	46.70	64.00	49.25	57.65
	5	42.60	67.10	48.70	57.40

4 = 780N

5 = MR

APPENDIX II: CORRELATION TABLES FOR THE HUMERUS.

II a. The whole sample for left and right sides.
II b. The Norwich sample for left and right sides.
II c. The *Mary Rose* sample for left and right sides.

Left

	length	Pbreadth	Dbreadth	diamhead	Mmaximum	Mminimum	circ	Hlesstub
length	1.000	0.618	0.464	0.575	0.328	0.417	0.431	0.234
Pbreadth	0.618	1.000	0.597	0.860	0.453	0.559	0.507	0.392
Dbreadth	0.464	0.597	1.000	0.548	0.426	0.456	0.520	0.281
diamhead	0.575	0.860	0.548	1.000	0.362	0.411	0.412	0.210
Mmaximum	0.328	0.453	0.426	0.362	1.000	0.623	0.843	0.164
Mminimum	0.417	0.559	0.456	0.411	0.623	1.000	0.745	0.134
circ	0.431	0.507	0.520	0.412	0.843	0.745	1.000	0.159
Hlesstub	0.234	0.392	0.281	0.210	0.164	0.134	0.159	1.000
Dlesstub	0.191	0.220	0.239	0.239	0.226	0.092	0.149	0.309
Gtuber	0.331	0.515	0.455	0.474	0.368	0.377	0.417	0.315
Tor	0.244	0.205	0.186	0.204	-0.030	0.011	-0.089	0.123

	Dlesstub	Gtuber	Tor
Dlesstub	1.000	0.155	-0.066
Gtuber	0.155	1.000	0.210
Tor	-0.066	0.210	1.000

Right

	maxlen	PB	DB	HD	Midmax	Midmin	Cir	HLtub
maxlen	1.000	0.634	0.522	0.652	0.431	0.468	0.473	0 253
PB	0.634	1.000	0.573	0.885	0.390	0.459	0.392	0.411
DB	0.522	0.573	1.000	0.580	0.437	0.458	0.476	0.285
HD	0.652	0.885	0.580	1.000	0.355	0.432	0.356	0.381
Midmax	0.431	0.390	0.437	0.355	1.000	0.579	0.789	0.048
Midmin	0.468	0.459	0.458	0.432	0.579	1.000	0.694	0 055
Cir	0.473	0.392	0.476	0.356	0.789	0 694	1.000	0 024
HLtub	0.253	0.411	0.285	0.381	0.048	0.055	0.024	1.000
DLtub	0.217	0.260	0.117	0.251	0.066	0.006	-0.025	0.278
Gtuberos	0.367	0.392	0.367	0.423	0.250	0.348	0.276	0 213
Tors	0.007	0.054	-0.020	0.006	-0.080	-0.019	-0.106	-0.109

	DLtub	Gtuberos	Tors
DLtub	1.000	-0.027	-0.055
Gtuberos	-0.027	1.000	-0.026
Tors	-0 055	-0.026	1.000

b

Left

	LMAXL	LPB	LDB	LHD	LMSMAX	LMSMIN	LCIRC	LHLTUB
LMAXL	1.000	0.649	0.443	0.606	0.327	0.360	0.415	0.430
LPB	0.649	1.000	0.553	0.889	0.401	0.504	0.515	0.408
LDB	0.443	0.553	1.000	0.561	0.462	0.437	0.590	0.285
LHD	0.606	0.889	0.561	1.000	0.314	0.377	0.407	0.183
LMSMAX	0.327	0.401	0.462	0.314	1.000	0.674	0.886	0.152
LMSMIN	0.360	0.504	0.437	0.377	0.674	1.000	0.770	0.158
LCIRC	0.415	0.515	0.590	0.407	0.886	0.770	1.000	0.224
LHLTUB	0.430	0.408	0.285	0.183	0.152	0.158	0.224	1.000
LDLTUB	0.213	0.169	0.146	0.248	0.262	0.085	0.216	0.245
LGTUB	0.316	0.486	0.460	0.464	0.365	0.361	0.414	0.325
LTOR	0.331	0.223	0.275	0.242	-0.014	0.080	0.111	0.110

	LDLTUB	LGTUB	LTOR
LDLTUB	1.000	0.267	-0.193
LGTUB	0.267	1.000	0.289
LTOR	-0.193	0.289	1.000

Right

	RMAXL	RPB	RDB	RHD	RMSMAX	RMSMIN	RCIRC	RHLTUB
RMAXL	1.000	0.668	0.511	0.691	0.420	0.427	0.464	0.435
RPB	0.668	1.000	0.539	0.892	0.379	0.464	0.358	0.455
RDB	0.511	0.539	1.000	0.582	0.571	0.488	0.547	0.374
RHD	0.691	0.892	0.582	1.000	0.363	0.449	0.354	0.432
RMSMAX	0.420	0.379	0.571	0.363	1.000	0.581	0.821	0.086
RMSMIN	0.427	0.464	0.488	0.449	0.581	1.000	0.662	0.106
RCIRC	0.464	0.358	0.547	0.354	0.821	0.662	1.000	0.122
RHLTUB	0.435	0.455	0.374	0.432	0.086	0.106	0.122	1.000
RDLTUB	0.192	0.218	0.083	0.226	0.057	0.064	0.065	0.398
RGTUB	0.414	0.481	0.358	0.525	0.245	0.288	0.209	0.208
RTOR	0.090	0.011	0.008	0.007	-0.049	-0.062	-0.013	-0.352

	RDLTUB	RGTUB	RTOR
RDLTUB	1.000	0.030	-0.105
RGTUB	0.030	1.000	0.056
RTOR	-0.105	0.056	1.000

C

Left

	Lmaxl	Lpb	Ldb	Lhead	Lmsmax	Lmsmin	Lcirc	Lhltub
Lmaxl	1.000	0.549	0.508	0.500	0.324	0.525	0.451	-0.188
Lpb	0.549	1.000	0.684	0.780	0.552	0.655	0.462	0.350
Ldb	0.508	0.684	1.000	0.484	0.326	0.485	0.365	0.262
Lhead	0.500	0.780	0.484	1.000	0.447	0.466	0.376	0.264
Lmsmax	0.324	0.552	0.326	0.447	1.000	0.496	0.744	0.184
Lmsmin	0.525	0.655	0.485	0.466	0.496	1.000	0.684	0.069
Lcirc	0.451	0.462	0.365	0.376	0.744	0.684	1.000	0.004
Lhltub	-0.188	0.350	0.262	0.264	0.184	0.069	0.004	1.000
Ldltub	0.154	0.318	0.410	0.250	0.154	0.108	0.031	0.434
Llgtub	0.347	0.521	0.394	0.400	0.367	0.387	0.383	0.279
Ltor	0.132	0.214	0.081	0.194	-0.046	-0.073	-0.346	0.161

	Ldltub	Llgtub	Ltor
Ldltub	1.000	-0.036	0.095
Llgtub	-0.036	1.000	0.165
Ltor	0.095	0.165	1.000

Right

	Rmaxl	Rpb	Rdb	Rhead	Rmsmax	Rmsmin	Rcirc	Rhltub
Rmaxl	1.000	0.567	0.548	0.564	0.467	0.537	0.501	-0.037
Rpb	0.567	1.000	0.639	0.872	0.421	0.458	0.457	0.351
Rdb	0.548	0.639	1.000	0.565	0.249	0.428	0.401	0.155
Rhead	0.564	0.872	0.565	1.000	0.357	0.412	0.373	0.303
Rmsmax	0.467	0.421	0.249	0.357	1.000	0 606	0.723	-0.008
Rmsmin	0.537	0.458	0.428	0.412	0.606	1.000	0.765	-0.009
Rcirc	0.501	0.457	0.401	0.373	0.723	0.765	1.000	-0.125
Rhltub	-0.037	0.351	0.155	0.303	-0.008	-0 009	-0.125	1.000
Rdltub	0.254	0.317	0.085	0.264	0.128	-0.111	-0.165	0.114
Rgtub	0.251	0.189	0.353	0.146	0.311	0.465	0.467	0.225
Rtor	-0.078	0.123	0.001	0.043	-0.145	0.036	-0.222	0.136

	Rdltub	Rgtub	Rtor
Rdltub	1.000	-0.251	0.068
Rgtub	-0.251	1.000	-0.082
Rtor	0.068	-0.082	1.000

APPENDIX III: CORRELATION TABLES FOR THE FEMUR.

III a. The whole sample for left and right sides.
III b. The Norwich sample for left and right sides.
III c. The *Mary Rose* sample for left and right sides.

a

Left

	MAXL	PHYSL	APD	MLD	APmid	MLmid	APdist	MLdist
MAXL	1.000	0.996	0.433	0.265	0.442	0.436	0.471	0.366
PHYSL	0.996	1.000	0.386	0.279	0.444	0.442	0.462	0.372
APD	0.433	0.386	1.000	0.157	0.591	0.431	0.438	0.356
MLD	0.265	0.279	0.157	1.000	0.242	0.678	0.301	0.239
APmid	0.442	0.444	0.591	0.242	1.000	0.476	0.673	0.406
MLmid	0.436	0.442	0.431	0.678	0.476	1.000	0 415	0.328
APdist	0.471	0.462	0.438	0.301	0.673	0.415	1.000	0.486
MLdist	0.366	0.372	0.356	0.239	0.406	0.328	0.486	1.000
circ.	0.546	0.550	0.608	0.494	0.873	0.747	0.676	0.493
HD	0.591	0.564	0.427	0.427	0.358	0.418	0.399	0.259
condyles	0.667	0.660	0.344	0.320	0.400	0.422	0.407	0.360
LengLC	0.623	0.617	0.416	0.299	0.383	0.432	0.444	0.305
LengMC	0.612	0.604	0.370	0.447	0.331	0.501	0.448	0.215
BreaLC	0.587	0.581	0.196	0.275	0.450	0.297	0.527	0.353
BreaMC	0.372	0.389	0.135	0.448	0.246	0.418	0.179	0.338
Greatroc	0.398	0.378	0.482	0.317	0.294	0.362	0.317	0.351
Lesstroc	0.156	0.137	0.233	0.150	0.084	0.142	0.142	0.028
Arc	0.567	0.576	0.381	0.049	0.382	0.305	0.300	0.315
SubT	0.286	0.293	0.232	-0.051	0.352	0.184	0.125	0.087
HDN	0.475	0.456	0.222	0.387	0.087	0.333	0.228	0.254
ANG	0.159	0.136	0.055	-0.289	0.037	-0.261	0.078	0.238

	circ.	HD	condyles	LengLC	LengMC	BreaLC	BreaMC	Greatroc
circ.	1.000	0.468	0.524	0.503	0.447	0.466	0.420	0.414
HD	0.468	1.000	0.699	0.633	0.568	0.504	0.285	0.444
condyles	0.524	0.699	1.000	0.762	0.750	0.641	0.348	0.588
LengLC	0.503	0.633	0.762	1.000	0.707	0.467	0.444	0.456
LengMC	0.447	0.568	0.750	0.707	1.000	0.580	0.414	0.452
BreaLC	0.466	0.504	0.641	0.467	0.580	1.000	0.217	0.464
BreaMC	0.420	0.285	0.348	0.444	0.414	0.217	1.000	0.479
Greatroc	0.414	0.444	0.588	0.456	0.452	0.464	0.479	1.000
Lesstroc	0.143	0.267	0.250	0.280	0.160	0.197	0.157	0.300
Arc	0.426	0.237	0.400	0.421	0.449	0.338	0.290	0.183
SubT	0.334	0.077	0.286	0.312	0.302	0.209	0.115	0.198
HDN	0.213	0.550	0.423	0.510	0.504	0.423	0.417	0.398
ANG	-0.040	0.022	-0.014	0.014	-0.164	0.016	0.032	-0.016

	Lesstroc	Arc	SubT	HDN	ANG
Lesstroc	1 000	0.019	0.062	0.166	0.180
Arc	0.019	1.000	0.387	0.122	-0.009
SubT	0.062	0.387	1.000	-0.020	-0.189
HDN	0.166	0.122	-0.020	1.000	-0.055
ANG	0.180	-0.009	-0.189	-0.055	1.000

Right

	HNECK	ANGH	Mlength	Plength	APdia	MLdia	APpilas	MLpilas
HNECK	1.000	0.036	0.565	0.559	0.195	0.378	0.148	0.376
ANGH	0.036	1.000	0.333	0.307	0.060	-0.276	0.065	-0.191
Mlength	0.565	0.333	1.000	0.997	0.414	0.349	0.477	0.363
Plength	0.559	0.307	0.997	1.000	0.368	0.352	0.475	0.378
APdia	0.195	0.060	0.414	0.368	1.000	0.198	0.586	0.345
MLdia	0.378	-0.276	0.349	0.352	0.198	1.000	0.241	0.696
APpilas	0.148	0.065	0.477	0.475	0.586	0.241	1.000	0.442
MLpilas	0.376	-0.191	0.363	0.378	0.345	0.696	0.442	1.000
APpoplit	0.261	0.016	0.487	0.473	0.466	0.333	0.698	0.414
MLpoplit	0.230	0.147	0.322	0.333	0.347	0.237	0.406	0.357
circum	0.244	0.002	0.495	0.499	0.566	0.497	0.898	0.712
diamhead	0.604	0.020	0.593	0.591	0.354	0.477	0.377	0.371
bicondyl	0.498	0.105	0.662	0.660	0.404	0.372	0.483	0.374
llatcond	0.572	0.100	0.648	0.636	0.394	0.407	0.414	0.413
lmedcond	0.555	0.002	0.641	0.631	0.386	0.459	0.325	0.391
blatcond	0.459	0.081	0.546	0.545	0.355	0.372	0.358	0.348
bmedcond	0.430	0.188	0.530	0.537	0.173	0.381	0.441	0.542
Gtroch	0.323	0.218	0.401	0.381	0.466	0.278	0.263	0.239
Ltroch	0.211	0.142	0.231	0.233	0.279	0.236	0.086	0.150
Bchord	0.248	0.075	0.567	0.567	0.300	0.111	0.353	0.146
subtense	0.058	0.045	0.285	0.290	0.337	-0.117	0.509	0.045

	APpoplit	MLpoplit	circum	diamhead	bicondyl	llatcond	lmedcond	blatcond
APpoplit	1.000	0.443	0.703	0.415	0.495	0.554	0.511	0.519
MLpoplit	0.443	1.000	0.515	0.157	0.415	0.340	0.265	0.444
circum	0.703	0.515	1.000	0.423	0.538	0.498	0.394	0.395
diamhead	0.415	0.157	0.423	1.000	0.715	0.668	0.657	0.541
bicondyl	0.495	0.415	0.538	0.715	1.000	0.778	0.733	0.661
llatcond	0.554	0.340	0.498	0.668	0.778	1.000	0.831	0.586
lmedcond	0.511	0.265	0.394	0.657	0.733	0.831	1.000	0.620
blatcond	0.519	0.444	0.395	0.541	0.661	0.586	0.620	1.000
bmedcond	0.444	0.441	0.575	0.445	0.495	0.572	0.483	0.360
Gtroch	0.278	0.280	0.339	0.443	0.586	0.484	0.369	0.421
Ltroch	0.139	0.245	0.150	0.199	0.299	0.224	0.197	0.395
Bchord	0.312	0.264	0.305	0.211	0.376	0.469	0.402	0.225
subtense	0.203	0.133	0.368	0.166	0.263	0.272	0.188	0.104

	bmedcond	Gtroch	Ltroch	Bchord	subtense
bmedcond	1.000	0.292	0.167	0.253	0.175
Gtroch	0.292	1.000	0.431	0.197	0.203
Ltroch	0.167	0.431	1.000	-0.006	-0.064
Bchord	0.253	0.197	-0.006	1.000	0.455
subtense	0.175	0.203	-0.064	0.455	1.000

Left

	LL1	LL2	LAPD	LMLD	LAPPIL	LMLPIL	LAPPOP	LMLPOP
LL1	1.000	0.996	0.469	0.259	0.531	0.369	0.497	0.418
LL2	0.996	1.000	0.391	0.276	0.531	0.378	0.492	0.427
LAPD	0.469	0.391	1.000	0.070	0.635	0.300	0.424	0.380
LMLD	0.259	0.276	0.070	1.000	0.200	0.762	0.338	0.257
LAPPIL	0.531	0.531	0.635	0.200	1.000	0.421	0.774	0.438
LMLPIL	0.369	0.378	0.300	0.762	0.421	1.000	0.426	0.294
LAPPOP	0.497	0.492	0.424	0.338	0.774	0.426	1.000	0.486
LMLPOP	0.418	0.427	0.380	0.257	0.438	0.294	0.486	1.000
LCIRC	0.578	0.581	0.614	0.495	0.904	0.706	0.756	0.488
LHD	0.629	0.593	0.525	0.355	0.476	0.384	0.373	0.294
LBICON	0.692	0.673	0.382	0.330	0.472	0.433	0.451	0.412
LLC	0.612	0.595	0.389	0.244	0.452	0.362	0.461	0.272
LMC	0.594	0.583	0.305	0.400	0.283	0.416	0.445	0.199
LBLC	0.747	0.739	0.347	0.447	0.565	0.452	0.705	0.507
LBMC	0.585	0.599	-0.007	0.431	0.048	0.492	0.272	0.410
LGT	0.446	0.395	0.473	0.296	0.387	0.304	0.438	0.457
LLT	0.295	0.278	0.270	0.200	0.180	0.265	0.187	0.025
LCH	0.467	0.497	0.335	-0.172	0.386	0.141	0.271	0.217
LBOW	0.073	0.088	0.236	-0.145	0.379	-0.057	0.217	0.079
LHDN	0.482	0.442	0.214	0.284	0.104	0.290	0.118	0.137
LANG	0.337	0.307	0.216	-0.131	0.092	-0.124	0.093	0.343

	LCIRC	LHD	LBICON	LLC	LMC	LBLC	LBMC	LGT
LCIRC	1.000	0.536	0.547	0.507	0.368	0.645	0.422	0.417
LHD	0.536	1.000	0.719	0.699	0.537	0.609	0.394	0.511
LBICON	0.547	0.719	1.000	0.805	0.764	0.679	0.564	0.612
LLC	0.507	0.699	0.805	1.000	0.703	0.620	0.469	0.459
LMC	0.368	0.537	0.764	0.703	1.000	0.715	0.529	0.478
LBLC	0.645	0.609	0.679	0.620	0.715	1.000	0.560	0.682
LBMC	0.422	0.394	0.564	0.469	0.529	0.560	1.000	0.448
LGT	0.417	0.511	0.612	0.459	0.478	0.682	0.448	1.000
LLT	0.260	0.554	0.267	0.310	0.190	0.275	0.217	0.168
LCH	0.340	0.218	0.334	0.383	0.410	0.227	0.448	-0.148
LBOW	0.259	0.007	0.119	0.185	0.175	0.245	0.070	0.086
LHDN	0.229	0.584	0.446	0.523	0.449	0.435	0.549	0.413
LANG	0.067	0.237	0.128	0.115	-0.023	0.074	0.179	0.067

	LLT	LCH	LBOW	LHDN	LANG
LLT	1.000	0.086	0.135	0.240	0.275
LCH	0.086	1.000	0.343	-0.004	0.124
LBOW	0.135	0.343	1.000	-0.014	-0.251
LHDN	0.240	-0.004	-0.014	1.000	0.126
LANG	0.275	0 124	-0.251	0.126	1.000

Right

	RL1	RL2	RAPD	RMLD	RAPPIL	RMLPIL	RAPPOP	RMLPOP
RL1	1.000	0.997	0.487	0.307	0.494	0.308	0.519	0.377
RL2	0.997	1.000	0.425	0.319	0.487	0.334	0.511	0.391
RAPD	0.487	0.425	1.000	0.148	0.703	0.317	0.575	0.493
RMLD	0.307	0.319	0.148	1.000	0.127	0.705	0.311	0.182
RAPPIL	0.494	0.487	0.703	0.127	1.000	0.317	0.761	0.465
RMLPIL	0.308	0.334	0.317	0.705	0.317	1.000	0.334	0.240
RAPPOP	0.519	0.511	0.575	0.311	0.761	0.334	1.000	0.451
RMLPOP	0.377	0.391	0.493	0.182	0.465	0.240	0.451	1.000
RCIRC	0.521	0.529	0.657	0.438	0.896	0.633	0.742	0.533
RHD	0.589	0.581	0.410	0.444	0.428	0.389	0.429	0.176
RBICON	0.724	0.725	0.430	0.320	0.506	0.379	0.524	0.461
RLC	0.638	0.628	0.363	0.320	0.402	0.349	0.521	0.342
RMC	0.712	0.708	0.317	0.419	0.269	0.329	0.467	0.252
RBLC	0.687	0.699	0.427	0.456	0.420	0.476	0.646	0.612
RBMC	0.704	0.711	0.108	0.268	0.363	0.409	0.505	0.453
RGT	0.384	0.351	0.362	0.294	0.270	0.212	0.342	0.386
RLT	0.301	0.320	0.307	0.311	0.221	0.276	0.241	0.305
RCH	0.479	0.488	0.301	-0.122	0.379	0.047	0.301	0.218
RBOW	0.162	0.162	0.305	-0.350	0.487	-0.117	0.221	0.220
RHDN	0.513	0.491	0.211	0.284	0.124	0.303	0.146	0.105
RANG	0.490	0.452	0.168	-0.184	0.156	-0.153	0.080	0.352

	RCIRC	RHD	RBICON	RLC	RMC	RBLC	RBMC	RGT
RCIRC	1.000	0.464	0.571	0.473	0.330	0.569	0.501	0.288
RHD	0.464	1.000	0.720	0.685	0.657	0.577	0.501	0.485
RBICON	0.571	0.720	1.000	0.834	0.744	0.766	0.663	0.629
RLC	0.473	0.685	0.834	1.000	0.837	0.621	0.688	0.488
RMC	0.330	0.657	0.744	0.837	1.000	0.648	0.557	0.398
RBLC	0.569	0.577	0.766	0.621	0.648	1.000	0.617	0.575
RBMC	0.501	0.501	0.663	0.688	0.557	0.617	1.000	0.208
RGT	0.288	0.485	0.629	0.488	0.398	0.575	0.208	1.000
RLT	0.295	0.194	0.396	0.246	0.235	0.556	0.307	0.447
RCH	0.307	0.150	0.287	0.440	0.410	0.134	0.215	0.001
RBOW	0.331	0.144	0.168	0.270	0.099	0.124	0.002	0.077
RHDN	0.219	0.650	0.489	0.523	0.564	0.456	0.392	0.307
RANG	0.085	0.063	0.231	0.196	0.145	0.342	0.372	0.136

	RLT	RCH	RBOW	RHDN	RANG
RLT	1.000	-0.070	-0.049	0.135	0.108
RCH	-0.070	1.000	0.449	0.112	0.303
RBOW	-0.049	0.449	1 000	0 011	0.043
RHDN	0.135	0.112	0.011	1.000	0.078
RANG	0.108	0.303	0.043	0.078	1.000

Left

	LL1	LL2	lapd	lmld	lappil	lmlpil	lappop	lmlpop
LL1	1.000	0.996	0.341	0.261	0.331	0.512	0.459	0.217
LL2	0.996	1.000	0.340	0.269	0.337	0.518	0.447	0.211
lapd	0.341	0.340	1.000	0.248	0.539	0.572	0.462	0.291
lmld	0.261	0.269	0.248	1.000	0.288	0.577	0.252	0.205
lappil	0.331	0.337	0.539	0.288	1.000	0.540	0.535	0.366
lmlpil	0.512	0.518	0.572	0.577	0.540	1.000	0.400	0.374
lappop	0.459	0.447	0.462	0.252	0.535	0.400	1.000	0.517
lmlpop	0.217	0.211	0.291	0.205	0.366	0.374	0.517	1.000
lcirc	0.507	0.516	0.597	0.489	0.834	0.794	0.566	0.508
lhd	0.569	0.556	0.307	0.506	0.218	0.455	0.436	0.227
lbicon	0.582	0.585	0.250	0.315	0.288	-0.394	0.359	0.161
llc	0.603	0.610	0.420	0.380	0.274	0.516	0.439	0.287
lmc	0.590	0.581	0.406	0.524	0.376	0.605	0.485	0.116
lblc	0.349	0.341	0.077	0.109	0.338	0.180	0.385	0.093
lbmc	0.249	0.270	0.216	0.485	0.355	0.383	0.136	0.306
lgt	0.265	0.280	0.428	0.308	0.206	0.391	0.284	0.178
llt	-0.098	-0.108	0.145	0.072	-0.058	-0.037	0.082	-0.037
lch	0.597	0.583	0.393	0.156	0.400	0.439	0.366	0.307
lbow	0.415	0.414	0.196	-0.018	0.328	0.381	0.036	0.016
lhdn	0.408	0.409	0.172	0.470	0.059	0.367	0.369	0.289
lang	-0.009	-0.012	-0.104	-0.440	-0.017	-0.396	0.063	0.161

	lcirc	lhd	lbicon	llc	lmc	lblc	lbmc	lgt
lcirc	1.000	0.392	0.485	0.493	0.540	0.325	0.429	0.407
lhd	0.392	1.000	0.716	0.580	0.634	0.427	0.246	0.400
lbicon	0.485	0.716	1.000	0.668	0.695	0.550	0.231	0.529
llc	0.493	0.580	0.668	1.000	0.686	0.241	0.441	0.419
lmc	0.540	0.634	0.695	0.686	1.000	0.390	0.361	0.374
lblc	0.325	0.427	0.550	0.241	0.390	1.000	0.021	0.257
lbmc	0.429	0.246	0.231	0.441	0.361	0.021	1.000	0.502
lgt	0.407	0.400	0.529	0.419	0.374	0.257	0.502	1.000
llt	-0.019	0.013	0.177	0.207	0.060	0.073	0.119	0.334
lch	0.513	0.272	0.364	0.397	0.391	0.310	0.232	0.232
lbow	0.393	0.133	0.385	0.384	0.344	0.113	0.116	0.208
lhdn	0.184	0.544	0.322	0.466	0.522	0.346	0.357	0.288
lang	-0 141	-0.185	-0.167	-0.086	-0.331	-0.044	-0.035	-0.088

	llt	lch	lbow	lhdn	lang
llt	1.000	-0.124	-0.052	0.035	0.066
lch	-0.124	1.000	0.353	0.068	-0.071
lbow	-0.052	0.353	1.000	-0.114	-0.127
lhdn	0 035	0.068	-0.114	1.000	-0.200
lang	0 066	-0.071	-0.127	-0.200	1.000

C

Right

	rl1	rl2	rapd	rmld	rappil	rmlpil	rappop	rmlpop
rl1	1.000	0.997	0.267	0.370	0.442	0.415	0.482	0.182
rl2	0.997	1.000	0.246	0.363	0.445	0.420	0.465	0.186
rapd	0.267	0.246	1.000	0.214	0.452	0.366	0.375	0.111
rmld	0.370	0.363	0.214	1.000	0.374	0.687	0.380	0.271
rappil	0.442	0.445	0.452	0.374	1.000	0.583	0.618	0.315
rmlpil	0.415	0.420	0.366	0.687	0.583	1.000	0.527	0.488
rappop	0.482	0.465	0.375	0.380	0.618	0.527	1.000	0.489
rmlpop	0.182	0.186	0.111	0.271	0.315	0.488	0.489	1.000
rcirc	0.465	0.465	0.480	0.560	0.905	0.789	0.666	0.506
rhd	0.592	0.597	0.274	0.504	0.313	0.352	0.417	0.105
rbicon	0.537	0.531	0.324	0.426	0.426	0.360	0.481	0.265
rlc	0.642	0.626	0.399	0.525	0.413	0.498	0.644	0.282
rmc	0.512	0.494	0.437	0.508	0.381	0.471	0.629	0.208
rblc	0.297	0.283	0.298	0.300	0.265	0.288	0.395	0.180
rbmc	0.405	0.412	0.199	0.465	0.488	0.597	0.443	0.433
rgt	0.346	0.337	0.480	0.223	0.245	0.240	0.281	0.127
rlt	0.119	0.110	0.215	0.131	-0.088	0.016	0.020	0.142
rch	0.608	0.592	0.201	0.247	0.317	0.221	0.390	0.192
rbow	0.327	0.330	0.299	-0.010	0.541	0.150	0.219	-0.045
rhdn	0.579	0.587	0.084	0.442	0.147	0.432	0.449	0.277
rang	0.243	0.244	0.017	-0.349	-0.008	-0.213	-0.076	0.019

	rcirc	rhd	rbicon	rlc	rmc	rblc	rbmc	rgt
rcirc	1.000	0.379	0.501	0.536	0.475	0.262	0.614	0.374
rhd	0.379	1.000	0.725	0.661	0.663	0.500	0.428	0.397
rbicon	0.501	0.725	1.000	0.672	0.695	0.483	0.374	0.520
rlc	0.536	0.661	0.672	1.000	0.809	0.505	0.510	0.472
rmc	0.475	0.663	0.695	0.809	1.000	0.544	0.431	0.310
rblc	0.262	0.500	0.483	0.505	0.544	1.000	0.166	0.263
rbmc	0.614	0.428	0.374	0.510	0.431	0.166	1.000	0.315
rgt	0.374	0.397	0.520	0.472	0.310	0.263	0.315	1.000
rlt	-0.001	0.182	0.175	0.172	0.121	0.277	0.115	0.388
rch	0.304	0.242	0.391	0.461	0.310	0.184	0.256	0.223
rbow	0.397	0.157	0.283	0.224	0.197	0.000	0.229	0.209
rhdn	0.251	0.562	0.458	0.616	0.520	0.411	0.427	0.248
rang	-0.057	-0.004	0.020	0.048	-0.133	-0.158	0.116	0.324

	rlt	rch	rbow	rhdn	rang
rlt	1.000	-0.014	-0.130	0.248	0.206
rch	-0.014	1.000	0.383	0.266	-0 040
rbow	-0.130	0.383	1.000	-0.005	0.110
rhdn	0.248	0.266	-0.005	1.000	0.057
rang	0.206	-0.040	0.110	0.057	1.000