A STUDY

of

THE SHOULDER ARCHITECTURE

of

THE SHEEP

involving

A COMPARISON

between

THE ROMNEY AND CHEVIOT BREED TYPES

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SECTION I

INTRODUCTION AND REVIEW OF LITERATURE

In the wild state, the body form of ungulates is determined by two factors:- (1) the animal's necessity to cover ground in search of food and to escape its enemies and (2) its need to convert efficiently the food it obtains into energy for its maintenance and for the performance of the first factor.

Another set of environmental responses, those incidental to the perpetuation of the race, appear to have but little influence on the bodily form of the ungulate (Howell, 1944). Hence, in the main, the musculature, skeleton, internal organs and the distribution of fat deposits in such species as the wild cattle or the wild sheep in their evolutionary response to environment would be governed by locomotive demands and the form from which a new adaptation evolved. As pointed out by Simpson (1949):- "in the evolution of a species..... the surviving organisms must meet the minimum requirements of life in an available environment and changes can only occur on the basis of what already exists." This latter factor is sometimes overlooked or not given enough emphasis in animal improvement investigations, but it is all important and probably the main reason why most adaptations are not absolutely perfect and why the selection applied by the domestic animal breeder for meat improvement cannot produce such rapid results as would be hoped.

In the improvement of the meat qualities in the sheep some account has to be taken of the animal's functional demands. The animal must first be able to thrive and be able to reproduce in the environment in which it is reared before much attention can be paid to selection for the meat qualities demanded by the consumer of mutton and lamb. It must be conceded that much of the artificial selection for meat improvement can very well be in the opposite direction to natural selection. This is most likely where the animal is reared in an easy and protected environment. As the conditions under which the domesticated animal is reared become more difficult, the more is the pressure exerted by selection of a natural character.

Although the recorded origins of the various breeds of sheep of the British Isles are, in most cases, not more than 150 years old, it has been held that the geographical environment has had no small part in shaping the various breed conformations. A flat terrain, for example, would result in small differences in conformation from those that would arise in rough and mountainous country. One difficulty encountered in attempting to get a picture of some particular breed type at some time in its history is that a true description of the prevailing type is rarely given. Given instead are the breeders' ideals or what the observer visualizes the type should be. Thus the part played by artificial selection in the changing of a breed type to the type as it is known today is not always clear. However, one fact is relatively clear. That is the fact that in the earlier origins of the British breeds of sheep there was very little cross-breeding between districts and each district evolved a distinct type. Also the crossing that did occur (more lately) is fairly well recorded.

Whether or not slight physical differences make one animal more adapted to a certain topography is a hard question to answer in the sheep or in any other species. Certain obvious differences which are usually termed adaptations can be identified but smaller variations are more difficult to sort out. This is especially true in domestic animals where such things as "Breeders' fancies" come into the picture. The first part of the problem is, obviously, the sorting out and classification of differences. This involves the thorough observation of a correct sample and the application of statistical procedures to determine whether these variations are real and not a product of eye appraisal and imagination. Then the difference, if real, is ready for application of a tentative hypothesis as to the origin or cause of the variation.

Just such a problem is posed by the situation of the Romney breed of sheep as contrasted with the Cheviot breed. The Romney Marsh breed originated in the marsh district of southeast England. This is flattish country and carries one of the densest sheep populations per acre in the world (Briggs, 1949). This fact alone suggest relatively little exercise. In the improvement of the Romney Marsh the records show only one other breed type brought in for improvement purposes. This was the English Leicester, a breed that originated in a fairly fertile area of rolling topography. This infusion of English Leicester blood was only temporary, however, as the Romney Marsh breeders found that fleece weights were lowered and the suitability of the resultant type to local conditions was reduced. So the breeders' aims reverted to the older type and the marks left by the infusion were wiped out (Nichols, 1928).

On the other hand the Cheviot breed type developed on the rugged terrain of the Cheviot hills. The very natüre of these hills demands an active and hardy type of sheep to search out the food necessary for its survival and self-perpetuation. There is some evidence to suggest that the Cheviot type is in part derived from the original "Tanfaced" sheep of these parts. However, at various times there have been infusions of the blood of other breeds and it is quite definite that the character of the breed has changed. The first infusions, though undocumented, were very likely with the Merino between 1480 and the late 1700s (Barber, 1914). Barber quotes a number of obscure references about the crossing of the original Cheviots with sheep containing "Spanish blood" (the Merino) which resulted in a more desirable type of wool produced. He goes on to say that the form and size of this resultant cross left much to be desired so further improvement led to the infusion of Lincolnshire sheep and sheep with a dash of the Dishley or Leicester blood. Another cross that affected the frame and wool of the Cheviot breed was one with the Ryeland or Hereford breed which was used at one time for grading up purposes. To the above types that contributed to the present day form of the Cheviot breed of sheep, Briggs (1949) adds the Black Faced Highland and the Southdown. However, it is quite likely that the introduction of the last two types was only of an experimental nature.

Because of the fact that the Romney and the breed used at one stage in attempting to improve it were developed on smooth to undulating country, this breed can be considered as essentially a lowland type of sheep. On the other hand the Cheviot and some of the breeds suspected of contributing to its present form were evolved in very rough and steep terrain. Hence, the Cheviot can be classed as a hill sheep.

Since the above two breed types were developed under such contrasting environments, it follows that basic differences in habit (for example, hill climbing habit as opposed to the less demanding level land locomotion) would doubtless develop. To maintain the hill climbing habit during the evolution of the present day Cheviot type, it is possible that certain characters were retained and/or more fully developed.

Both of the above breeds have been transplanted to New Zealand conditions, and while the Romney has undergone a certain amount of crossing with other breeds, its basic form is still similar to that of the sheep of the Romney Marsh. The average Cheviot in New Zealand, being a descendant of much more recent importations, even more closely resembles its cousins of the Cheviot Hills.

Among the characteristics that distinguish the Cheviot type of sheep from the Romney type is the conformation of the shoulder region. The Cheviot breed has sharp, pointed withers and rather sloping shoulders while the Romney type has fairly rounded shoulders and is relatively smooth over the withers. This feature makes the Cheviot type objectionable to a great many sheepmen who seek to justify this objection by accusing the Cheviot of carrying less meat. Less meat would mean less muscle and certainly this can be doubted in an animal of an active mountain type which (body weights being equal) would need proportionately greater muscular development to thrive on the hills. The probable answer lies in a slightly different distribution of muscular tissue, less fat and in certain skeletal differences. Herein lies the problem and objective in the present study. The logical attack to this problem would necessarily need to be in the following sequence:- firstly, a stocktaking in a reasonable sample of each breed type in order to establish any real differences in the shoulder architecture of the two breed types; secondly, if differences proved existent to find their anatomical determinant; and thirdly, an attempt to relate the type difference to the ecological background of the breed types under study.

In order to achieve the above objectives certain measuring techniques had to be devised. Since the project involved the use of radiography, the literature on this subject was reviewed, but most of it proved to be concerned with small animal work (dogs and cats) and yielded little information on the restraint of animals during radiography. No literature was located on the problem of X-raying the animal in the normal standing position (without restraint).

Next came the problem of the anatomy of the sheep and here again rarity of material on the subject was in evidence. Although Sisson's Anatomy of Domestic Animals, (1930), proved to be of great value insofar as muscle and bone descriptions were concerned, it did not adequately cover the anatomy of the sheep. Tschaggeny and Vermeulen (1922) have drawn up a very comprehensive atlas in colour which well illustrates the skeleton and musculature of the cow and this was consulted on certain anatomical questions. The German veterinary anatomist, St. Iwanoff, (1930), made a study of the fore-end of the sheep, but his report has mostly to do with the internal organs, blood vessels and nerves. In order to help fill this gap in knowledge of the anatomy of the sheep (particularly in the shoulder musculature and in the normal articulate angles of the bones of the pectoral lamb) a great deal of space is necessarily devoted to the purely anatomical aspect.

With regard to the above mentioned angulations, studies have been made by Bethcke (1930) on possible differences due to function in trotting horses and cavalry horses. In the elephant and certain extinct quadrupeds, Osborn (1900) reasoned that the articulate angles formed by the limb bones are an adaptation to body weight.

In connection with the shoulder architecture of the mammal, it was found that several studies had been made by various authors. Most of these concern either mammals in general or some animal unrelated to the domestic sheep. The most comprehensive article located concerning the shoulder architecture of mammals in general was written by Howell (1944), and it provides clues to the possible evolutionary origin of muscle groups and their components. Windle and Parsons (1901) have made a good, though sketchy, review of the muscles of the ungulate, but only major variations were mentioned while forms and relative sizes were excluded.

Concerning the relation of form to function, some background material has been provided by D'Arcy Thompson (1942) in a general treatise on "Growth and Form". In the ungulate, Howell's study (1944) on speed in animals provides some thoughts on the form of the animal as an adaptation for escape from its enemies. His book deals mainly with wild animals although the horse is dealt with as it is one of the most highly specialized of the mammals fitted for running. When attempting to express the actual movements of quadruped locomotion in mathematical terms, Rashevshy (1944 and 1946) admits that he can do no more than keep things on a purely abstract and theoretical level. He adds that the actual situations are much more complex and his formulae, difficult as they are, can only be simplified versions.

In the study of the form of bones, Murray (1936) presents a number of ideas and theories concerning the shape of bones, but most of the workers whose research he reviews were experimenting with special reference to the form of human bones. However, Hammond (1932) has made a rather exhaustive study on the difference in the bone shape of the semi-wild types of sheep as contrasted with bone proportions in the improved mutton breeds.

Much good dissection work has been done in reference to the mutton qualities of sheep. Mainly, these investigations have been concerned with immature sheep and studies of growth and the dissections were done on purely a bone, muscle and fat separation basis.

McKenzie and Marshall (1917) made a preliminary study of Merino cross Shropshire sheep in which they classified the sheep into Shropshire-like and Merino-like groups. One of the points used in classifying was an "over the shoulders" appraisal by palpation. From the palpation of the shoulder region they concluded that the shape of the Merino-like shoulders (sharp, narrow and not well covered) was due to:- The height of the dorsal spines of the vertebrae, the height of the scapula in relation to the vertebrae and the extent to which the scapulae converged towards the middle line. They also indicate that the development of flesh "over the shoulder" is not as good in this type as in the Shropshire-like sheep.

In conclusion, it was felt that rather than go into an exhaustive review of literature, most of which did not deal directly with the subject at hand, it would be better to make more reference to the literature during the analyses of results. In this manner the points can be more fully dealt with as they come to light.

SECTION II

ANATOMY OF THE SHOULDER REGION IN THE SHEEP.

In order to familiarize the reader with the anatomy of the region studied, it was felt that a special section should be devoted to a rather complete description of the bones of the thoracic limb, the thoracic vertebrae, the muscles of the shoulder and the fore-limb, cartilage of the scapula and the ligamentum nuchea.

In preparing the following descriptions, Sisson's (1930) "Anatomy of Domestic Animals" was closely consulted as well as Tschaggeny and Vermeulen's (1922) atlas of the cow. Also, help was provided by an article by Windle and Parsons (1901) on the muscles of the ungulates. In addition a paper by Howell (1936) on the shoulder architecture of the mammal was closely followed.

A. The Long Bones of the Pectoral Limb and the Thoracic Vertebrae.

There are four major bones in the thoracic limb:- the scapula, the humerus, the radius-ulna and the metacarpus (third or large metacarpal bone). In the sheep the posterior border of the scapula and the ventral line of the thoracic vertebrae form an angle of about 35 degrees. The angle between the scapula and the humerus (the shoulder angle) when the animal is standing is approximately 95 degrees and the angle between the humerus and the radius-ulna (the elbow angle) is about 115 degrees.

1. The scapula and the cartilage of the scapula.

The scapula is the uppermost bone of the limb column. It is triangular shaped and is rather flat. It is placed on the anterior and dorsal portion of the wall of the thorax and has two surfaces, three angles and three borders.

The lateral surface is divided by a bony ridge called the spine of the scapula, which runs generally in the distal-proximal direction. This spine divides the lateral surface into two lateral fossae:- the supraspinous fossa on the anterior side and the infraspinous fossa on the posterior side. In the sheep the spine of the scapula is placed so that the supraspinous fossa is about one-fourth the size of the infraspinous fossa. The medial surface of the scapula is rather hollowed out to form the subscapular fossa. The spine of the scapula ends at its distal terminus in a pointed projection called the acromium and at its proximal end on what is called the vertebral root of the spine of the scapula.

The anterior border has an extended S form or contour and is quite a thin edge until it begins to round off toward the distal end.

The posterior border is almost straight and fairly thick for its entire length. The angle which this border makes with the horizontal is approximately 50 degrees in the sheep. The vertebral border is on the proximal end and is nearly straight with a slight suggestion of being convex. The anterior and posterior borders converge to the neck of the scapula which, in its cross-section, has roughly the shape of a 180 degree segment of a circle, the diameter being on the medial side of the neck of the scapula. The anterior and vertebral borders come together at the anterior angle of the scapula and the posterior and vertebral borders join at the posterior angle. In the sheep the anterior angle is fairly thin, and the posterior angle is thickened.

Distal to the neck of the scapula is the glenoid or articular angle which contains the surface that articulates with the humerus. The articulating surface is the glenoid cavity. This depression has an oval form of which a segment on the anterior and medial part is absent. This break in the oval outline is called the glenoid notch. Anterior to this is a projection called the tuber scapulae (or bicipital tuberosity). The medial part of the tuber scapulae has a small prominence called the coracoid process to which the tendon of the coracobrachialis attaches.

The ventral border of the cartilage of the scapula fits along the vertebral border of the scapula. In the sheep, it is wider than the vertebral border and tends to overlap at both the posterior and anterior angles. Its width appears to be about one-fourth greater than the vertebral border and its ventral-dorsal depth is roughly one-third of its length.

2. The humerus.

The humerus is one of the long bones of the limb, and it lies between the scapula and the radius-ulna in the limb column. It is a heavy and columnar bone and in the sheep (when standing) it inclines at an angle of about 135 degrees with the horizontal. The bone's shaft lies between the proximal and the distal extremities.

The shaft of the humerus, which is roughly cylindrical in form, has four surfaces:- the lateral, medial, posterior and anterior surfaces.

The lateral surface appears to be the largest and has a suggestion of a spiral form. It is on this surface that the anterior portion of the brachialis muscle fits.

The medial surface contains the teres tubercle which, in the sheep, is not much more than a roughened spot about one-third of the way from the proximal end of the shaft. This surface is smooth except for the teres tubercle.

The posterior surface is the top ridge of the shaft and is rounded for almost the entire length of the shaft.

The anterior surface has roughly the shape of a very long right triangle whose hypotenuse is concave. The proximal end of this curved hypotenuse is the deltoid tuberosity.

The point or collar where the shaft joins the proximal extremity is known as the neck of the humerus. The well defined part of the neck on the lateral, posterior and part of the medial side is sometimes referred to as the surgical neck of the humerus.

In addition to the neck the proximal extremity of the humerus contains the head, two tuberosities and the intertuberal groove. The head is the round dome-shaped articulating surface that fits into the glenoid cavity of the scapula.

The lateral tuberosity of the humerus is lateral to the head and projects beyond it in an anterior direction. This tuberosity is very prominent in the sheep. Lateral to the anterior part of the head and medial to the anterior part of the lateral tuberosity is the intertuberal groove. The anterior part of the lateral tuberosity curves to some extent over this groove.

The posterior part of the lateral tuberosity is relatively thin and leaf-shaped and as the ridge proceeds anteriorly, it broadens until it is quite thick at the anterior part, where it gives attachment to the supraspinatus muscle.

The medial tuberosity on the proximal extremity is not very pronounced in the sheep. It consists of a relatively broad posterior part whose edges converge in an anterior direction to form the pointed anterior part.

The distal extremity of the humerus, which contains the surface that articulates with the radius-ulna, has two condoyles of unequal size:- the larger medial condoyle and the smaller lateral condoyle. The lateral condoyle, as well as the division of the shaft to which it is joined, projects laterally to some extent. The medial and lateral surfaces of these condoyles furnish surfaces of attachment for many of the muscles of the fore-arm.

3. The radius-ulna.

This is really two bones, the radius and the ulna, which are very closely joined. They are placed in the limb column between the hunerus and the proximal row of carpal bones.

The radius is another long bone consisting of a shaft and two extremities. From the lateral aspect, the shaft is curved for its entire length, the concave part of the curve being on the anterior side of the bone. The shaft in cross-section is oval with the posterior surface flatter than the anterior surface.

The proximal extremity of the radius is somewhat flattened on its dorsal surface which carries two depressions into which fit the condyles of the humerus. On the medial side is a rather sharp projected edge known as the radial or bicipital tuberosity. The lateral tuberosity is quite pronounced and is sometimes known as the tuberositas proximalis lateralis.

The ulna is the smaller of the two bones and its distal end is joined to the proximal extremity and the shaft of the radius. This is on the posterior side of the extremity and surface of the radius. Between the connection on the extremity and the shaft there is an opening called the interosseous space. There is no distal interosseous space as in the case of the ox. After the distal part of the shaft of the ulna fuses with the shaft of the radius, it remains fused for the remainder of its length.

The proximal extremity of the ulna is the major part and the largest portion of this bone. It projects upward from the dorsal surface of the radius and inclines backward to some extent.

This extremity consists of two surfaces, two edges and a summit. The medial surface is slightly concave and the lateral surface is convex. Viewed laterally, the anterior and posterior edges of the ulna both have a convex outline. The summit is the most proximal part of the ulna.

4. The metacarpus.

The third or large metacarpal bone was the one studied. It is another long bone and consists of a shaft and two extremities. A cross-section on any part of the shaft would resemble a 180 degree segment of a circle, the posterior surface representing the diameter of the above circle.

The proximal extremity articulates with the distal row of the carpal bones and the distal extremity articulates with the first phalanx and the proximal sesamoid bones.

5. The thoracic vertebrae.

In the sheep the thoracic vertebrae are thirteen in number although sometimes there are twelve or fourteen. In the sheep these lie in a plane that is roughly 10 to 20 degrees from the horizontal.

Each vertebra consists of a body, two transverse processes, two articular processes and one spinous process. The body is on the ventral side and is short and constricted in the middle. On the posterior and anterior surfaces of the body is the centrum. The vertebral foramen which carries the spinal cord is in a position dorsal to the body, ventral to the dorsal process and medial to the transverse processes. The arch is the part of the vertebral body that carries these processes. The articular processes are small and contain two oval facets. The transverse processes project laterally from the arch and each contains a facet for articulation with a rib. These processes tend to rise dorsally so that a groove is formed between them and the spinous or dorsal process.

The spinous process of the vertebra is large in comparison with other thoracic vertebral processes. It is thin and slopes upwards and backwards (except the twelfth and thirteenth spines which slope forward). Transversely, these spinous processes are thicker in the distal and proximal ends than they are in the middle. The first spinous process is relatively short as compared with the second, third and fourth processes which are the highest of the thoracic vertebrae. Posterior from the fourth vertebra, the spinous processes gradually diminish in height.

B. The Ligamentum Nuchea.

The ligamentum nuchea is made up of two parts:- the funicular part and the lamellar part. The funicular part consists of the main anterior-posterior strands which arise on the occipital bone of the skull and lie along the back line until they merge into the lumbo-dorsal region of the supraspinous ligament. The lamellar part forms a connection between the cervical vertebrae and the funiccular part and the spines of the thoracic vertebrae.

In the sheep, the funicular part is divided into two separate lateral strands which are merged antero-posteriorly to a point just anterior to the second thoracic dorsal spine where they make a definite split. One strand carries on posteriorly on each side of the dorsal region of the thoracic spines. After the division, the two strands are connected by a thin, membraneous tissue. In the thoracic region these strands are part of the origin of the trapezius and rhomboideus muscles. In the sheep, after the division into two separate parts, the dorsal tips of the second to sixth thoracic spinous processes were the highest point in the thoracic region.

C. The Musculature.

The muscles are grouped in the sections or divisions given by Howell (1936) in his account on the Shoulder Architecture of Mammals. These groups and their components are shown in Table 1 as adjusted from Howell's general list for mammals to fit those present in the sheep.

TABLE 1.

GROUPING OF THE MUSCULATURE OF THE PECTO AL LIMB.

1. Branchiomeric Group	Trapezius Brachiocephalicus Omo-transversarius
2. Dorsal Division:-	
a) Suprazonal group	Serratus Rhomboideus
b) Shoulder derivatives:-	
1) Thoraco-dorsal matrix	Latissimus dorsi Teres major
2) Axillary matrix	Teres minor Subscapu aris Deltoideus (pars acromialis) (pars scapularis)
c) Elbow derivatives	Tensor fasciae antibrachii Triceps brachii Anconeus
3. Ventral Division:-	
a) Infrazonal group	Sterno-scapularis
b) Shoulder derivatives:-	
1) Pectoral matrix	Deep pectoral
2) Anterior coracoid matrix	Superficial pectoral Supraspinatus Infraspinatus
3) Posterior coracoid matrix	Coracobrachilais
c) Elbow derivatives	Brachialis Biceps brachii

The panniculus carnosus was listed by Howell (1936) in the pectoral matrix section of Table 1, but in this study this muscle was omitted as its function concerns more the twitching of the integument rather than the movement of the limb. Sisson (1930) calls this muscle the musculus cutaneus trunci and does not list it with the muscles of either the shoulder girdle or the shoulder. Sisson's grouping of the muscles of the thoracic limb of the ox is shown in Table 2.

TABLE 2.

SISSON'S GROUPING OF
THE SHOULDER MUSCULATURE OF THE OX.

I. Muscles of the shoulder girdle

Trapezius	Brachiocephalicus
Omo-transversarius	Superficial pectoral
Rhomboideus	Deep pectoral
Latissimus dorsi	Serratus ventralis

II. Muscles of the shoulder

The deltoids	Subscapularis
Supraspinatus	Teres major
Infraspinatus	Coraco-brachialis
Teres minor	

III. Muscles of the arm

Biceps brachii
Triceps brachii
Tensor fasciae antibrachii

(Although not listed for the ox, it is supposed that Sisson would place the anconeus and the brachialis in this group. This is their place in his grouping given for the horse.)

Howell's (1936) classification is probably the better because he considers the evolutionary origin of the muscles involved. In an earlier account Howell (1933) lists some general considerations which supports this classification on the evolution of the main groups and how these can be more or less traced from their evolutionary origin. He has some doubt about the origin and placing of the subscapularis. Howell thinks it possible that the anterior portion of it may have originated through the encroachment of a part of the supraspinatus. If true, this theory would place the anterior part of the subscapularis under the heading of the "anterior coracoid matrix" in Table 1. For the purposes of this study, it is listed in the group derived from the "axillary matrix".

1. The branchiomeric group

This group, which Romer (1950) says originated from the gill bars in the evolution of the tetrapod, is present in most of the vertebrates (including the primitive ones). The gill bars evolved into the trapezius musculature, and Romer goes on to state that slips of this formed the muscles that complete the group (brachiocephalicus and omo-transversarius in sheep).

All of this group is a part of those muscles that connect the pectoral limb with the head, neck and trunk. Leach (1946) states that the trapezius group and the rhomboideus group in mammals are particularly concerned with holding the scapula close to the vertebral column. It is a fact that the branchiomeric group as given in Table 1 has its insertion lateral to the bones of the thoracic limb. This makes it the outside member of the muscle cradle from which the fore part of the animal body swings on its anterior piers or limbs.

In the sheep there are three muscles in this group:- the trapezius, the brachiocephalicus and the omo-transversarius.

a) The trapezius.

This muscle, apart from its function as a trunk-limb connector, has the action of elevating the shoulder. Its muscle origin, although varying as illustrated by Beaton and Barry (1942), is generally as follows:- the anterior part on the ligamentum nuchae and the posterior part on the supraspinous ligament from the dorsal spines of the thoracic vertebra. Its insertion is mainly along the spine of the scapula, thus making it possible for it to move the scapula forward and upward as well as backward and upward.

b) The brachiocephalicus and omo-transversarius muscles.

In this study, these two muscles were treated as one muscle because in the sheep they are in very close association with one another. The dorsal border of the omo-transversarius lies next to the ventral border of the anterior portion of the trapezius. The anterior end of the omo-transversarius crosses under the dorsal edge of the anterior part of the brachiocephalicus as they converge on the wing of the atlas which is their common origin. For the omo-transversarius, the origin is the wing of the atlas and the insertion is the spine of the scapula and fascia of the shoulder. Its action supplements that of the brachiocephalicus. The brachiocephalicus has its origins on the wing of the atlas, the occipital bone of the , skull, the ligamentum nuchea the muscle rectus capitus ventralis major and on a tendon from the mandible. Its insertion is on the deltoid tuberosity of the humerus and the arm and shoulder fascia. Its action in locomotion is mainly in assisting in drawing forward the limb. When the animal is standing it helps to move the head.

2. <u>The dorsal division</u>.

This division is comprised of three groups:- the suprazonal group, the shoulder derivatives and the elbow derivatives.

a) The suprazonal group.

This musculature forms a part of that which attachs the limb to the trunk. It forms its limb connections, as is indicated by its title, medial to the bones of the limb and in the dorsal regions of this bone column. In addition to its function of attachment of the limb, this group acts as a shock absorber system to receive and dampen the jolts of locomotion. This is particularly true of the serratus muscle which is much the larger of the two in this group in the sheep. Romer (1950) terms these muscles the slings of the trunk and says they are derivatives of the external oblique muscle (obliquus externus) with the rhomboideus probably the later in evolutionary origin. The latter is found only in mammals and one of its special duties is to keep the scapula at more or less a constant distance from the thorax.

1) The serratus muscles

In the sheep, the divisions of the serratus ventralis, such as Sisson (1930) describes for the horse, are not so clearly defined. Its two parts are the serratus cervicis and the serratus thoracis. The serratus cervicis lies between the last few cervical vertebrae (its origin) and medial to the anterior angle of the scapula (its insertion). The serratus thoracis (much the larger of the two parts) is a large, fan-shaped muscle with its ventral edge presenting a rather jagged appearance at its points of origin on the ribs. The surface that spreads over the ribs is the main origin of this muscle. It is inserted on the medial surface of the dorsal section of the scapula. This insertion extends to the adjacent portion of the cartilage of the scapula. Its chief action in locomotion is to elevate the thorax and to assist in the same motion as previously described for the trapezius.

2) The rhomboideus.

This muscle which serves as a lateral connection between the scapula and the trunk did not seem to be so clearly divisible into the cervical and thoracic parts in the sheep as is indicated in Sisson (1930) for the horse. It has its origins in the same regions but underneath those of the trapezius muscle and is inserted on the costal side of the cartilage of the scapula. This muscle supplements the action of the anterior part of the trapezius in drawing the scapula upward and forward.

b) The shoulder derivatives of the dorsal division.

In the sheep, there are six muscles in this group and these are further divided into two parts:- those muscles arising or evolving from the thoraco-dorsal matrix and those coming from the axillary matrix.

1) The thoraco-dorsal matrix section.

In this section there are two muscles:- the latissimus dorsi and the teres major. Although the teres major is from limb bone to limb bone (scapula to humerus), Howell (1936) places it in this group, as he believes that it was originally a part of the latissimus dorsi which, as a trunk-limb connector, certainly arose from the thoraco-dorsal matrix. Howell's opinion is supported by that of Romer (1950). Both of these muscles, as will be seen later, are involved in the flexing of the shoulder joint.

(a) The latissimus dorsi.

Although this muscle is a trunk-limb connector, its main function is that of providing locomotive power rather than acting as a support muscle as most of the previous muscles have done. It is a relatively large, flat, fan-shaped muscle that has a broad origin in the lumbo-dorsal fascia. Its general pattern of muscle fibres are roughly at right-angles to those of the serratus thoracis which borders it medially in its ventral part. Its tendon of origin in the sheep does not seem to extend as far forward over the anterior part of the upper thorax as Tschaggeny and Vermeulen (1922) illustrate for the ox. The ventral part of the origin blends with the fascia that lies over the oblique abdominis externus muscle. The insertions of the latissimus dorsi are into tendons which connect with:- (1) the teres tubercle of the humerus (with the teres major); (2) with the aponeurosis on the medial side of the long head of the triceps brachii; and (3) with a tendon shared with the deep pectoral muscle. Its functions are to assist in lifting the humerus upward and backward. When the limb is held stationary this muscle helps in drawing the trunk forward. It is one of the main opposing muscles to the brachiocephalicus in limb action.

(b) The teres major.

As mentioned before, it is the common opinion among zoologists that this muscle evolved from the latissimus dorsi and became a muscle of the shoulder joint. It lies partially in a groove medial and anterior to the anterior border of the latissimus dorsi. The origin of the teres major is just ventral to the posterior angle of the scapula (on the scapula) and it is inserted into the common tendon shared with the latissimus dorsi which connects to the humerus at the teres tubercle. Its action involves helping to close the scapulo-humeral angle and thus to lift the arm. In addition, it is concerned with adduction of the arm (rotating it medially) as can be visualized by noting its attachment on the medial side of the humerus.

2) The axillary matrix section.

In the sheep, there are four muscles in this section:- the subscapularis, the teres minor, the deltoideus pars acromialis and the deltoideus pars scapularis. In regard to the evolutionary origin of the last three muscles, Howell(1936) says that the deltoids and the teres minor arose as a single sheet from the membraneous girdle, a fact which is indicated by the close relationship of their respective innervation.

(a) The subscapularis.

This muscle which occupies the subscapular fossa branches into three fairly distinct heads in its dorsal end. Most of the fossa is occupied by its origin and these three heads fuse as the scapula narrows towards its distal end. The subscapularis inserts into a tendon which passes over the glenoid notch of the scapula and attaches to the posterior eminence of the medial tuberosity of the humerus. Its obvious action is to help in adduction of the humerus.

(b) The teres minor.

This is a rather small muscle that is medial to the distal portion of the infraspinatus and to the deltoideus pars scapularis muscles. Its origin is partly on the distal and posterior part of the infraspinatus fossa of the scapula (where it begins to round off) and partly on the lower middle part of the posterior border of the scapula. Its insertion is on and near the proximal region of the deltoid tuberosity of the humerus. It has an opposing action to that of the subscapularis in that it helps in abducting the humerus. In addition it assists in closing the scapulo-humeral angle (flexing of the shoulder joint).

(c) The deltoids.

In the sheep, there are two easily distinguishable deltoid muscles. Howell (1936) says that in perissodactyla there are, in reality, three muscles which may in different species be in partial or complete fusion. The two which Sisson (1930) gives for the ox, the pars acromialis and the pars scapularis, are easily located in the sheep.

The deltoideus pars acromialis has its origin on the acromion of the spine of the scapula and is inserted on the humerus at the deltoid tuberosity. In this position it can help to abduct the arm and to flex the shoulder joint. It is a small muscle and rather flat, but it was found to be the larger of the two deltoids in all sheep dissected.

The deltoideus pars scapularis is the smaller member of the pair in sheep. Its origin is on the posterior border of the scapula and the aponeurosis that covers the infraspinatus. It is inserted partly into the fascia that covers the lateral head of the triceps brachii. At its ventral end it begins to fuse with the pars acromialis. Its action is to complement that of the deltoideus pars acromialis as previously described.

c) The elbow derivatives of the dorsal division.

There are three muscles in this group of which the triceps brachii is the most important. The other two, the tensor fasciae antibrachii and the anconeus are merely the members of the supporting cast which enable the triceps brachii to function more efficiently. As regards the evolutionary origin of this group, Howell (1936) holds with the theory that some fibres of the latissimus dorsi migrated down the arm to form a slip with triceps action. He is undecided as to whether the dorso-epitrochlearis (tensor fasciae antibrachii in Sisson, 1930) evolved later from the triceps brachii or as another slip from the latissimus dorsi.

1) The tensor fasciae antibrachii.

This is a long, thin muscle which follows the posterior border of the triceps brachii. In the sheep, its origin is on the posterior border of the scapula dorsal to the origin of the long head of the triceps brachii. It is inserted into a short tendon which blends partially with that of the insertion of the triceps brachii on the olecranon. The action of the tensor fasciae antibrachii is to tense the fasciae of the fore-arm and to help extend the elbow joint.

2) The anconeus.

This is another very small muscle in the sheep, and it lies along the posterior aspect of the humerus. It has its origin on the distal half of this surface and is inserted on the lateral side of the olecranon. Its function concerns the assisting of extension of the elbow joint.

3) The triceps brachii.

This muscle, as its name implies, has three main divisions:- the long head (also called the triceps longus, caput magnum or caput longum tricipitis); the lateral head (also known as the triceps lateralis, caput medium, or caput laterale tricipitis) and the medial head (also called the triceps medialis, caput marvum or caput mediale tricipitis). The triceps brachii fills the triangle which is formed between the shoulder joint, the olecranon and the posterior angle of the scapula and when taken as a whole is the largest of the muscles in the sheep that have their origin on the fore-limb.

The long head is by far the largest of the three heads of this muscle in the sheep. It is roughly three times as big as the lateral head which is the next largest. Its origin is the posterior border of the scapula (along roughly three-fourths of this border), and it is inserted on the dorsal regions of the olecranon of the ulna. It has a dual action in flexing the shoulder joint and in extending the elbow joint.

The lateral head of the triceps brachii, as its name indicates, lies on the lateral surface of the arm and covers the ventral part of the long head. Its points of origin are from the deltoid tuberosity toward and including part of the neck of the scapula. This lateral head is inserted into a tendinous sheet that connects with the lateral side of the olecranon and also blends in with the tendon of the long head of the triceps brachii. Its action complements that of the long head in extending the elbow joint.

The medial head of the triceps brachii lies on the posterior and medial edge of the humerus and in the sheep extends for the entire length of the shaft of that bone. In fact, a portion of its origin is on the neck of the humerus just below the posterior part of the articulating surface of the head. Part of its origin is by means of a tendinous sheet to the surface of the bone which it borders. It is inserted on the medial and anterior part of the summit of the olecranon and its main action is to help extend the elbow joint.

3. The ventral division.

There are three sections in this division:- the infrazonal group, the shoulder derivatives and the elbow derivatives.

a) The infrazonal group.

There is one muscle only in this group in the sheep. It is the sterno-scapularis. There appears to be a great deal of confusion about this muscle in the literature reviewed. Windle and Parsons (1901) call this muscle the sterno-scapularis and found it to be absent in the Mouflon and rudimentary in the Fat-tailed sheep. They quote Chauveau (1891) who did not find it in sheep and also Lesbres (1897) who says that it is present in ruminants as a small bundle that joins the cephalo-humeral muscle. (brachiocephalicus). St. Iwanoff (1939) describes the muscle in his sheep dissection studies but calls it the pars clavicularis. In the ox, Sisson (1930) calls it the scapular portion of the deep pectoral, but this is not quite the right terminology for the sheep as it ends in or joins the brachiocephalicus. This muscle was observed medial to the anterior portion of the superficial pectoral. Its origin is on the ventral border of the anterior part of the sternum and it is inserted into the brachiocephalicus just ventral to the shoulder joint (also inserted into the fascia of the biceps brachii). It is a rather small, flat muscle and certainly not rudimentary as Windle and Parsons (1901) found in the Fat-tailed sheep. Howell (1944) says this muscle is used in fixation and is unimportant in locomotion.

b) The shoulder derivatives of the ventral division.

In most ungulates this group is divided into three sections:- the pectoral matrix, the anterior coracoid matrix and the posterior coracoid matrix.

1) The pectoral matrix.

In Howell's (1936) classification, the panniculus carnosus was included as was mentioned previously but this muscle was not treated in this study. This leaves only the deep pectoral in this group.

The deep pectoral is another of the trunk-limb connecting muscles, but its main function is to provide locomotive power rather than to bind the limb to the body. In the sheep it is a broad, sling-shaped muscle with a wide origin on the abdominal tunic and along the posterior part of the ventral aspect of the sternum. The deep pectoral is inserted on both the lateral and medial tuberosities of the humerus. It has great power in drawing the trunk forward if the limb is advanced and fixed by giving a strong downward and backward pull on the humerus. It is by far the largest of the muscles in the pectoral region.

2) The anterior coracoid matrix

Howell (1936) states that when the evolutionary change from the reptilian to mammalian type of posture occurred, the change in the position of the humerus provided a stimulus that split the coraco-humeral group. Some of the original matrix migrated dorsally becoming the supra- and infraspinatus and part went ventrally to form the pectoralis major (superficial pectoral).

(a) The superficial pectoral

In the sheep, this muscle is clearly divisible into two parts:- the relatively thick and short anterior part and the broad and very thin posterior section. Its origin is along the ventral border of the sternum. Due to the spreading nature of the superficial pectoral, it has two main insertions:- the fascia of the fore-arm and the deltoid tuberosity of the humerus. Its action in addition to that of tensing the fascia of the fore-arm is to assist in adducting the limb.

(b) The supraspinatus.

This is a relatively large muscle that in the sheep more than fills the supraspinous fossa of the scapula. This fossa and the anterior surface of the spine of the scapula are the origins of this muscle, and it is inserted mainly on the lateral tuberosity of the humerus on its anterior aspect. Its action is to extend the shoulder joint as well as aiding in binding this joint to help prevent dislocation.

(c) The infraspinatus.

This is the larger of the two that originate in the lateral fossae of the scapula. In the sheep it fills the infraspinous fossa with no overlapping of the posterior border of the scapula. It is inserted into a large tendon that connects on the lateral tuberosity of the humerus posterior to the insertion of the supraspinatus. Its functions include the abduction of the arm and the fixing of the shoulder joint to help prevent dislocation.

3) The posterior coracoid matrix.

In the sheep there is one small muscle (the coracobrachialis) in this section and Windle and Parsons (1901) are of the opinion that in the sheep it is the coracobrachialis medius. This muscle has its origin on the coracoid process of the scapula and is inserted on the humerus anterior to the teres tubercle. It assists in adducting the arm and in flexing the shoulder joint.

c) The elbow derivatives of the ventral division.

This group consists of two muscles in the sheep and their chief action is to flex the elbow joint. They are the brachialis and the biceps brachii.

1) The brachialis.

This muscle spirals around the humerus from its origin just back of the surgical neck of that bone. Its insertion is on the medial surface of the neck of the radius and on the ulna. Its function, as mentioned above, is to flex the elbow joint.

2) The biceps brachii.

Howell (1936) says that this muscle was derived from the brachialis. It lies on the ventral side of the humerus in the ungulate and has a tendinous origin on the tuber scapulae. In the sheep its insertion is a tendon that splits, one part attaching to the radial or bicipital tuberosity and the other on the ulna (Sisson, 1930). The action of the biceps brachii in locomotion is to flex the elbow joint.

In Table 3 a brief review of all the muscles of the shoulder region, which are given above, is presented. The table gives the origin and insertion of each muscle as well as its chief action.

TABLE 3.

MUSCLES OF THE SHOULDER REGION
AND THEIR ORIGIN, INSERTION AND ACTION.

Muscle	Origin	Insertion	Action (In locomotion)
Trapezius	Ligamentum nuchae spinous process of the thoracic vertebrae	Spine of scapula	Moves scapula forward and backward
Brachiocephalicus + omo-transversarius	Atlas, occipital bone ligamentum nuchea,etc.	Deltoid tuberosity of humerus, spine of scapula, shoulder fascia	Draws limb forward
Serratus thoracis	Lateral surface of ribs	Medial surface of scapula and cartilage.	Elevates the thorax, moves scapula.
Rhomboideus	Ligamentum nuchae, spinous processes of thoracic vertebrae	Medial side of cartilage of scapula	Rotates scapula, prevents lateral movement of scapula
Latissimus dorsi	Lumbo-dorsal fascia	Teres tubercle of humerus, triceps, deep pectoral	Lifts humerus upward and back
Teres major	Posterior angle of scapula	Teres tubercle	Flexes shoulder joint, adducts arm.
Subscapularis	Subscapular fossa	Medial tuberosity of humerus	Adducts humerus.
Teres minor	Infraspinous fossa, posterior border of scapula	Deltoid tuberosity of humerus.	Flexes shoulder joint.
Deltoids	Acromion of scapula, posterior border of scapula.	Deltoid tuberosity of humerus	Flexes shoulder joint, abducts arm.

TABLE 3 Continued.

Muscle	Origin	Insertion	Action (In locomotion)
Tensor fasciae anti-brachii	Posterior border of scapula	Triceps and olecranon	Tenses fasciae of forearm, extends elbow joint
Anconeus	Distal half of surface of humerus	Olecranon	Extends elbow joint
Triceps brachii	Posterior border of scapula, deltoid tuberosity of humerus, medial surface of humerus.	Olecranon	Extends elbow joint, flexes shoulder joint
Deep pectoral	Posterior part of sternum, abdominal tunic	Lateral and medial tuberosity of humerus.	Draws trunk forward
Sterno-scapularis	Ventral border of sternum	Brachiocephalicus and fascia of biceps.	-
Superficial pectoral	Ventral border of sternum	Fascia of forearm, deltoid tuberosity of humerus	Tenses fascia of forearm, adducts limb.
Supraspinatus	Supraspinous fossa of scapula	Lateral tuberosity of humerus	Extends shoulder joint.
Infraspinatus	Infraspinous fossa of scapula	Lateral tuberosity of humerus	Abducts arm
Coracobrachialis	Coracoid process of scapula	Medial surface of humerus	Adducts arm, flexes shoulder joint.
Brachialis	Neck of humerus	Medial side of radius and ulna	Flexes elbow joint
Biceps brachii	Tuber scapulae	Radial tuberosity	Flexes elbow joint

SECTION III

MATERIALS AND METHODS.

A. The Experimental Plan.

This study involves a comparison of the average Romney breed type and the average Cheviot breed type with special reference to the thoracic region and the pectoral limbs. The experimental animals were as nearly as possible a representative sample of ten animals from each breed type. In order to obtain data to draw this comparison of type, the live animals were first submitted to a series of measurements after which they were all photographed and radiographed.

The next step involved two slaughtering methods. Three animals of each breed type were embalmed with a formal saline solution and later were dissected. Six animals in each breed type were slaughtered in the ordinary manner. In the latter method, three of each breed were sectioned transversely while the remaining three of each breed type were dissected.

In selecting the animals for these three divisions, randomisation restricted on the basis of body weight was used. All twenty of the ewes were weighed and the heaviest in each breed type discarded. The remaining nine in each breed type group were divided into three groups by weight resulting in a light, medium and heavy weight group for each breed type. One animal was selected at random from each of the above weight groups for the application of the embalming technique. From the remaining two in each weight group one sheep was selected at random from each group for slaughter and dissection. The three animals then remaining went to the group for slaughtering and cross-sectioning. Thus it was hoped that a better balance of animals was ensured and a more legitimate comparison of treatments made possible.

The six formol saline fixed animals were again measured and radiographed after embalming and a dissection of the left fore-limb and shoulder followed.

The twelve carcasses of the ordinary slaughter group were photographed and carcass measurements taken. Two of these were radiographed. Three of each breed type group were dissected in the same manner as the fixed sheep. The remaining three of each breed type were cross-sectioned transversely and these sections photographed.

The experimental plan is illustrated in Figure 1.

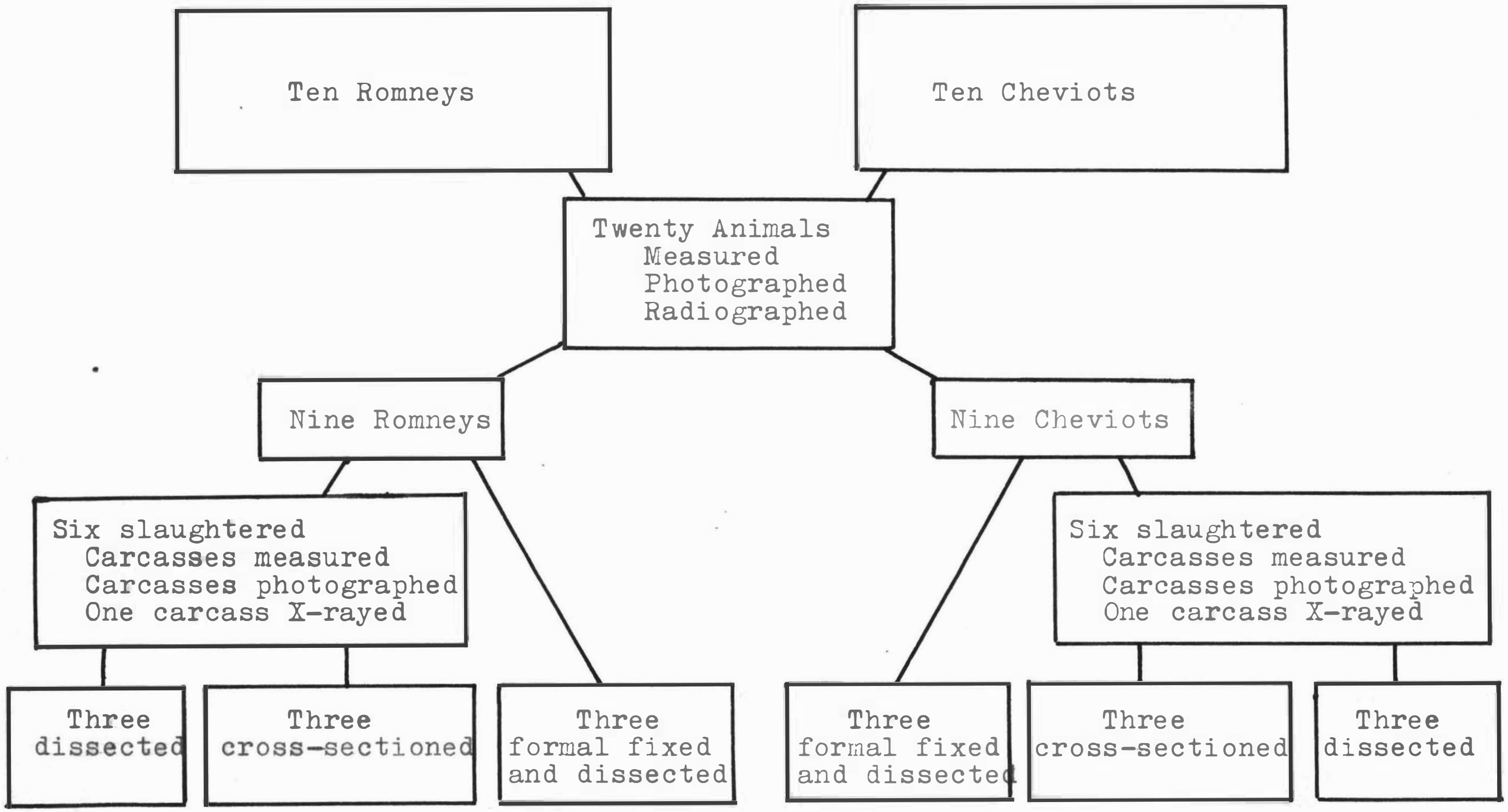


Fig.1.-- Diagrammatic Scheme of Experimental Plan

B. Selection and Training of the Animals.

The animals used in this study consisted of ten Romneys and ten seven-eighth blood Cheviots, the latter resulting from three topcrosses of Cheviot rams on Romney ewes. They were mature ewes, four and one-half years of age, and had been run on the Massey Agricultural College hill farm (Tua Paka) since birth. The Romney ewes were selected as being typical of the average New Zealand Romney cross that is run on North Island hill sheep farms. The selection was done soon after weaning when the ewes were beginning to rise in condition.

Since the experimental plan called for body measurements, live animal photographs and radiographs, the animals were given a short training period of three weeks in order to accustom them to handling. During most of this time the sheep were penned. Ample water and good lucerne hay were at all times available and a protein supplement (linseed nuts) was fed by hand. Towards the end of this taming period when the sheep would come into the pen in anticipation of the linseed nuts, they were let out in the adjacent pasture and the hay feeding was discontinued.

Approximately 150 hours were actually spent training the animals over the three weeks' period. This means that about seven and one-half hours was spent with each individual. Since some of the live animal measurements were taken during this period, this training time served a double purpose.

As a point of interest in connection with comparative breed behaviour and response to training, it was noted that the Cheviots learned to lead and to stand squarely in about ten days, whereas, the Romneys, even at the end of the training period, still did not lead and stand well. The Cheviots were alert and responsive to training, while the Romneys were sullen and stubborn. Tribe (1949) in his experiments on sheep behaviour preceptor responses seems to have mainly used the Cheviot breed. Although he gives no reason for this choice, this may be an indication of their greater "trainability."

Midway through the training period (12 February-5 March) the sheep were shorn as closely as possible in order to allow greater accuracy in taking body measurements and to avoid any effect which the wool (then about two to three inches long) might have in clouding the radiographs.

C. Measurements on the Live Animals.

1. Body weights.

The live weights were recorded at intervals during the training period. They were taken using a spring scale with the sheep in a weighing sling. Just prior to slaughter the weights were again recorded. Before this last weighing, the sheep had been subjected to a 10 hour starvation period.

2. Linear measurements.

The linear measurements undertaken in this study were height at withers, heart girth, depth of thorax and width between the lateral tuberosities of the humeri. These measurements were repeated on each animal using two different systems. In the first system, all the repeat measurements were collected by one observer. Before shearing, this observer took the above measurements on six successive days on each sheep. After shearing, all measurements were again taken on each animal on six different days. Thus, apart from a comparison of the breeds, it was possible to determine whether shearing had any effect on changing the accuracy of the measurements.

Near the end of the above mentioned training period the second system of repeat measures was put into operation. It involved three observers each taking the measurements twice, following the method used by Rae (1946). The three observers each took the series of measurements on two successive days. On each occasion, the sheep were taken at random and measured by the first observer, the process being then repeated for subsequent observers. Each observer completed all the measurements on all sheep before the next observer started measuring. Each observer measured all 20 ewes on the afternoon of one day, and the repeats were made on the morning of the following day.

The sheep, while being measured, were all standing squarely on a level, concrete floor.

a) Height at withers

This is the vertical distance between the floor level and the highest point over the withers. It was taken by the use of the sliding calipers shown in Figure 2 and in the manner illustrated in Figure 2. These calipers were well braced and remarkably free from play. While the base of this instrument rested on the floor, the sliding portion was dropped to the withers, a constant pressure being applied in all cases by the weight of this sliding arm of the calipers. Then the locking screw was tightened and the base to slide distance measured with a steel tape to the nearest 0.25 inch.

b) The heart girth.

The measurement was made using a flexible steel tape which was read to the nearest 0.25 inch. The tape was fitted around the heart girth at its least circumference just posterior to the lateral bulge of the shoulders. An attempt was made to use a standard tension on the tape for each sheep measured to assist in reducing error. An illustration of this measurement is found in Figure 3.

c) The depth of thorax.

This measurement is the distance between the highest vertical point on the withers to the lowest point on the sternum between the fore limbs, the line between the two points being in an almost vertical direction. The measurement was taken by resting the lower projection of the calipers firmly against the sternum so that this bar passed on a diagonal between the fore legs. Then the sliding portion of the calipers was dropped to the highest point of the withers as in the height of withers measurement, the locking screw tightened and the distance between the two bars measured to the nearest 0.25 inch using the steel tape. The method is shown in Figure 4.

d) Width between the tuberosities of the humeri.

For this measurement the calipers were placed over the sheep's neck as shown in Figure 5. The edge of the non-sliding arm was placed against the shoulder point of the right side and the other arm slid to the shoulder point of the opposite side.

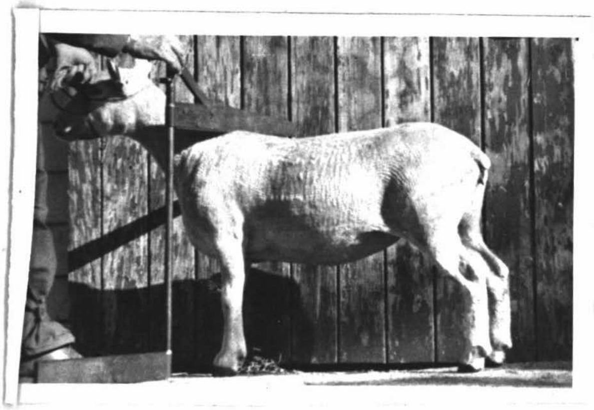


Fig.2.---Measurement of height at withers.

Fig.3.---Measurement of the heart girth.

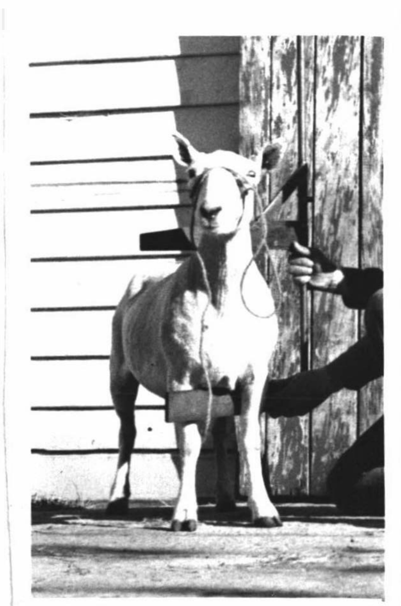


Fig.4.---Measurement of depth of thorax.

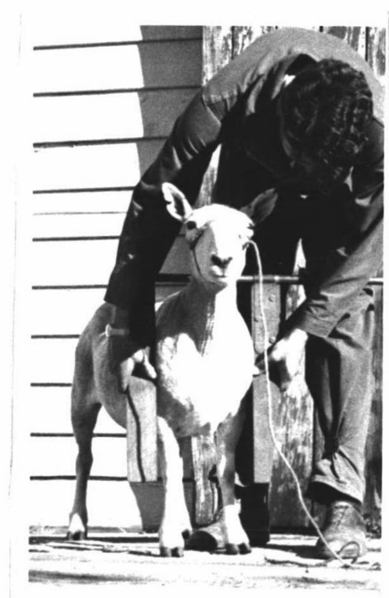


Fig.5.---Measurement of width between the tuberosities of the humeri.

The locking screw was tightened and the distance measured to the nearest 0.25 inch using the steel tape.

3. The "shoulder mould."

In order to get an idea of the general cross-sectional shape of the region under study on the live animal, a "shoulder mould" was made in the following manner:-

a) The first step was to establish by palpation the lateral tuberosities (tuberositas proximalis medialis) of the radii which are quite prominent on the live animal when it is standing squarely on both fore legs. The width between these two tuberosities was measured and set, using the above mentioned calipers when the sheep was standing naturally with equal weight on both fore legs.

b) The calipers in this set position were placed so they covered the edge of a sheet of paper. (Shown in Figure 6.)

c) Then a mould was taken of the shoulders by means of a rope wrapped tightly with soft wire. It was found that this device would hold a shape and yet be flexible enough to get a fairly accurate contour. When the sheep is standing normally and squarely on both fore legs, with head up and facing forward, the highest point of the withers is almost directly above the tuberosities of the radii. The rope was placed at the highest point of the withers and moulded around the shoulders in a vertical plane until the position of the tuberosities of the radii were again established. Holding these points the rope was laid on the paper with these points at the end of the calipers as shown above. Then tracings were made following the line of

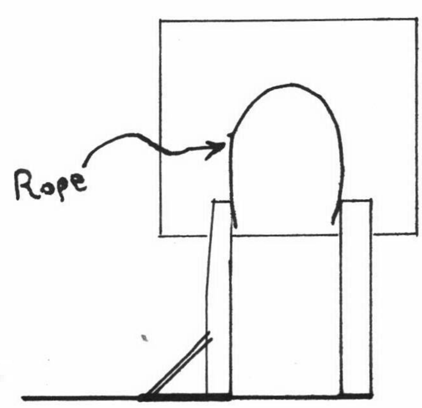


Fig. 6.--Line diagram showing the method of reproducing the shoulder mould.

the mould as taken.

d) Afterwards the area inside tracing was measured to the nearest square centimetre using a planimeter as described in F4.

D. Photography of Live Animals

All the ewes were photographed from three different angles in order that body proportions could be studied by enlarging all the pictures to the same scale, cutting out the pictures and re-photographing on graph paper. This method, although not accurate as far as taking measurements is concerned, (Phillips and Stoehr, 1945) has been used to study proportions with success. (Hammond, 1932) (McMeekan, 1940-41) However, Tanner and Weiner (1949) have found the photogrammetic technique fairly reliable in getting measurements on the living human. Their photography was done at a distance of 30 metres and the negatives were enlarged to one-eighth natural size.

The positions and distances used in the present study were as follows:-

1. Lateral view taken of all sheep

The camera position was fixed at twelve inches above the ground, a distance which was approximately one-half of the height at the withers of the sheep studied. The distance between the camera and subject was sixteen feet and all the sheep were posed so that their left hoofs were just inside a line perpendicular to the camera line. (See Figure 7.)

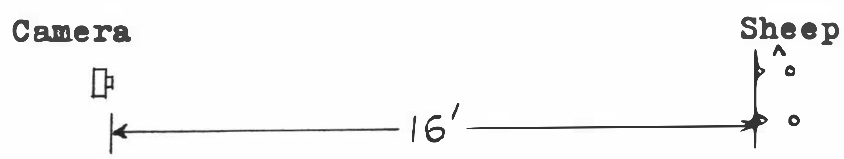


Fig. 7.—Line diagram showing camera set-up for photography of lateral view of the sheep.

2. Frontal view taken of all sheep.

The camera was fixed at the same height as above and the distance from the camera to a line on which the fore feet of the animals were placed, as shown in Figure 8, was 16 feet.

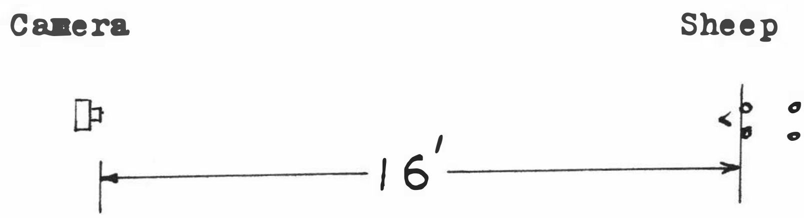


Fig. 8.--Line diagram showing camera set-up for photography of frontal view of the sheep.

3. Dorsal view taken of all sheep

The camera was fixed on a large tripod. The vertical camera to ground distance was $73\frac{1}{2}$ inches. Since the difference between the shortest and the highest animal in height at withers was not more than three inches, little error was introduced by the fact that one subject would be a little closer to the camera than would another. The greatest error in this view comes from not being able to place all the animals in exactly the same position.

E. Fluoroscopy and Radiography of the Live Animals.

An attempt was made to view the limb bones of the thoracic region (scapulae, humeri and radii-ulnae) of the live animal by means of the fluoroscopic attachment to the X-ray plant. The attempt was unsuccessful for two reasons. Firstly, it was not possible to get the complete darkness required for best results; and secondly, the region of the thorax is too thick to get a good image on the screen even when the X-ray plant was turned up to the maximum safe MA (milliamperes) for fluoroscopy with the plant used. The ribs could be picked out, but the bones of the limbs presented only dark, fuzzy-edged blobs. This region is the thickest on the animal as far as bone is concerned, since there are two layers of bones of the thoracic walls as well as the two sets of limb bones.

In order to keep the animals close against the X-ray plate which was kept at a constant distance of 36 inches from the X-ray tube, a wedge-shaped bail was constructed. It was decided that, although a clearer plate might be obtained by an oblique shot, the lateral shot would be best in order to minimize possible distortion of the natural articulate angles of the bones of the thoracic limb. In the resulting plate, it was easy to pick out the left limb bones from those of the right limb. In all cases the left side was studied as this was the side pressed against the plate.

The principle used in distinguishing between the two limbs on the X-ray plate is illustrated in Figure 9. As may

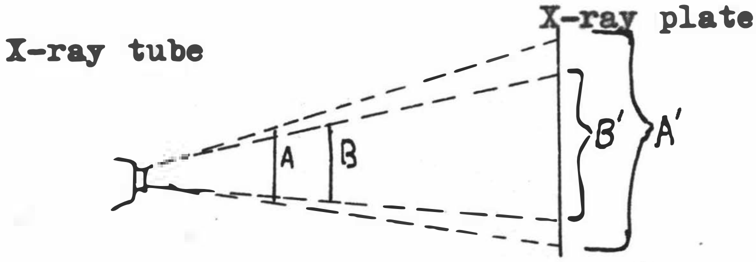


Fig. 9.—Line diagram showing principle used in identifying limb bones of the right and left leg on the X-ray plate. In the diagram "A" and "B" are of the same length but their respective images on the X-ray plate ("A'" and "B'") are of different sizes.

be readily seen from Figure 9, the bone nearer the plate will be smaller and closer to the normal size.

The setting used on the X-ray machine was:-

H9   20MA   ¾seconds   Distance-- 36 inches

The H value is a control in the machine that, when altered (assuming a constant MA (milliamperes), will change the Kv.p (Kilovolts-peak). The Kv.p (kilovolts-peak) in the above settings is 70.9.

With the long exposure used it was inevitable that some movement of the animal would take place. It so happened that six of the first twenty radiographs had to be repeated because of movement of the animal. The slightest movement, other than that of the breathing, will result in fuzziness and make definition difficult.

The setting to be used on the machine was worked out by a method of trial and error and, as was discovered later in further radiography, could be improved upon by decreasing the MA (milliamperes) and increasing the H value. However, the radiographs obtained were sufficiently satisfactory to define the points sought. Since no literature on the X-raying of sheep from the lateral thorax view was available, the setting suggested by Kirk (1937) in radiographing a Great Dane dog was used as a starting point.

To interpret the plates, use was made of a dark room safe-light from which the amber glass sheet had been removed. Under this amber glass was a plate of opal glass. On this the X-ray plates were placed and a sheet of architects' tracing paper was laid on top in order to trace outlines of the images needed to measure the various angles considered.

F. Formal Saline Fixation.

1. Method of fixation.

The ewes were first narcotized with an intravenous injection of Thicentone Sodium. After losing consciousness they were placed on a squared board against which they had been previously photographed.

They were banked into position by means of small partially filled sand bags. (Shown in Figure 10.) The observer directing the positioning was in a vertical position over the sheep. The live animal photographs were in his possession and the placement of the animals' body and limbs were oriented from the positions shown in the photographs. The observer-sheep distance was sixteen feet which was the camera-subject distance during the previous photographing of the animals. When the sheep's position, as shown by the photograph, was attained, an incision was made about half way up the neck on the left side just below the ventral edge of the brachiocephalicus. The jugular vein was then severed in order to insert a cannula through which the fixing solution flowed. The fixing solution was formal saline which contained 100 cc. of formalin and 8.5 gms. sodium chloride per litre of solution. The container of solution was about seven feet above the animal. As the formal saline flowed into one end of the vein, the contents of the blood stream flowed out the other. When the liquid flowing out became clear (being almost pure formal saline solution), the free end of the vein was tied and about two additional litres of the solution allowed to flow in. This was all the cadaver would take before pressure was built up to stop the flow. Twelve to fourteen litres of the solution were used on each animal. In a similar anatomical study St. Iwanoff (1939) used 7-8 litres of 8 per cent solution.

In order to ensure that the contents of the rumen were well saturated with the fixing solution, an additional amount of 50 cc. was injected through the stomach walls. This was to prevent possible fermentation and subsequent formation of gases which might have the effect of distorting the cadaver. The animals subjected to the fixing treatment were weighed prior to and after fixing. On the day following fixing the bodies were again photographed against the squared background from a vertical distance of sixteen feet.

On the day after the fixing process, the six cadavers were measured in the same manner as when they were alive. The measurements taken were:- heart girth, height at withers, depth of thorax and width between the tuberosities of the humeri. Three replications of each measurement were made on each cadaver. In addition a shoulder mould as previously described was taken.

2. Radiography of the fixed animals.

The formal saline fixed cadavers were placed in a position closely approximating their stance when X-rayed alive. This was done using the same equipment set at the identical positions used in the live animal radiography. These positions had been marked while the X-raying of the live animals had been in progress. In order to find a more suitable setting for penetrating the thoracic region, several more test settings were attempted using the previous setting as a guide. In the same setting that was used for the live animals, there appeared to be no difference resulting from the formal saline impregnation of the body tissues. In a setting of 25 MA (milliamperes) and a Kv.p (kilovolts-peak) of 72, the radiograph lacked contrast. However, when the MA (milliamperes) were lowered to 15 and the Kv.p (kilovolts-peak) increased to 83, the definition was greatly improved. The new setting used was:-

H11   15MA   ¾seconds   Distance 36 inches

3. Dissection of the fixed sheep

The dissection was muscle by muscle of all muscles of the left shoulder girdle, the muscles of the left shoulder and the arm muscles of the left fore limb. The left forearm muscles were treated as a group.

After the skin of the shoulder and arm region had been removed, the anterior portion of the panniculus carnosus was reflected. This muscle did not enter the study. However, the fat medial to it which was lateral to muscles that were removed was weighed. The fat lateral to and between all muscles dissected was removed and weighed. The fat between or lateral to the thoracic wall but medial to the deepest muscle dissected out was not removed. Muscle, tendon and periosteum removed whilst cleaning bones and muscles was weighed with the fat.

The same order was maintained throughout the dissection on all animals, and precautions were taken against any evaporation that might occur during the dissection period. The weather at the time was cool and damp and there was little air movement in the dissecting rooms, both factors which helped keep possible evaporation losses to a minimum. The dissection work was done by the same person throughout and each animal required between 12 to 14 hours dissection time. The muscles were lifted out, cleaned of fat and tendon, weighed, measured, cross-sections taken and volume obtained by immersion.

A list of the muscles dissected follows:-

Trapezius	Supraspinatus
Rhomboideus	Infraspinatus
Latissimus dorsi	Teres minor
Brachiocephalicus	Subscapularis
Omo-transversarous	Teres major
Superficial pectoral	Coraco-brachialis
Deep pectoral	Biceps brachii
Sterno-scapularus	Brachialis
Serratus thoracis	Tensor fasciae antibrachii
Deltoid pars acromialis	Triceps brachii
Deltoid pars scapularis	Anconeus

The muscles of the forearm were treated as one group in the weighing.

The bones that were dissected out and measured were:- the scapula, the humerus, the radius-ulna, the metacarpal and the thoracic vertebrae.

Positions of the above muscles and bones are shown in Figures 11, 12, 13, which illustrate different stages in the dissection procedure.

The cartilage of the scapula was removed from the scapula

Fig. 10.--Showing the animal banked into position with partially filled sand bags in preparation for fixing with formal saline solution.

Fig. 11.--Lateral muscles of the shoulder after the panniculus carnosus muscle has been reflected.

a, Trapezius; b, brachiocephalicus; c, omotransversarius; d, infraspinatus; e, latissimus dorsi; f, triceps brachii; g, tensor fasciae antibrachii; h, deltoideus pars scapularis.

Fig. 12.--Anatomy of the shoulder region after the removal of some of the lateral muscles.

a, Latissimus dorsi; b, deep pectoral; c, biceps brachii; d, supraspinatus; e, serratus thoracis; f, teres minor; g, scapula; h, cartilage of the scapula.

Fig. 13.--Ventro-lateral view of muscles of the pectoral limb.

a, Brachiocephalicus; b, superficial pectoral; c, deep pectoral; sterno-scapularis.

weighed to the nearest 0.1 gm., measured for width (antero-posterior) and for depth (ventro-dorsal). It was oriented on a sheet of paper and a tracing made around the edge. Later this outline was measured for area with the planimeter.

The ligamentum nuchae was measured for length both _in situ_ and when dissected out of the animal. It was also weighed and measured for depth and width. Actually, not the entire ligamentum nuchea was treated, but only the funnicular part of the ligament anterior to the cut made at the junction between the thoracic and lumbar vertebrae. This included most of the funnicular portion.

4. _Treatment of the muscles_

After each muscle had been cleaned of fat and tendon it was weighed to the nearest 0.1 gm. and then oriented on a sheet of paper in the approximate position it had occupied in the animal. The greatest width, the greatest length and the greatest depth were determined using a pair of dividers. After being spread to the proper dimension the dividers were placed on a steel rule and the reading was made to the nearest 0.1 cm. While the muscles were still on the sheet of paper a pencil outline of each one was drawn for future measurement of area. After this tracing the muscles were severed and an outline drawn of their cross-sections.

Following the above treatment, the volume of each muscle was determined by immersion. The water in the apparatus used drained from an overflow and the surface tension was afterwards decreased by adding three drops of Teepol. Then the muscle was immersed and the overflow collected in a vessel of known weight. When the overflow had stopped the surface tension was again decreased with three more drops of Teepol. The total overflow caused by the muscle was weighed to the nearest 0.1 gm.

Later a planimeter was used to determine the area within the traced outline of each muscle. This method of measuring area is quite accurate according to Burns and Clarkson (1949) who found that there was no error in the measurements of areas except in the cases of areas of less than 50 sq. mm. in which case the maximum error was three per cent and the average error 0.5 per cent.

In order to determine the accuracy of the planimeter used, tests were made on areas of known size. Two areas were tested (one of 25 sq. cm. and one of 200 sq. cm.) by measuring them 10 times each and calculating the standard deviation, the coefficient of variability and the average error. The coefficient of variability was calculated by dividing the standard deviation by the mean reading and multiplying by 100 to get it in a per cent form. The average error was calculated by dividing the spread by the mean reading and multiplying by 100. The results of these tests appear in Table 4.

TABLE 4

ACCURACY OF PLANIMETER.

Size of tested area	Standard Deviation	Coefficient of Variability	Average Error
25 sq. cm.	0.170	0.60%	2.14%
200 sq. cm.	0.736	0.37%	0.30%

Since most of the areas measured were between 25 and 200 sq. cm., very little error was introduced in the use of the planimeter. The most error in obtaining the muscle area probably arose in the tracing process.

5. <u>Treatment of the bones</u>

At this stage the bones were weighed only, the other measurements being left to a later time.

G. Treatment of the Freshly Killed Ewes.

1. Method

Twelve of the ewes were slaughtered in the ordinary manner, six being for dissection study and six for cross-sectional work. The sheep for the dissection studies were slaughtered at intervals of two days while the ones for the cross-sectioning were all killed at one time. Prior to slaughter, the sheep were penned for about ten hours, and killing commenced about 4:30 P.M. At the time of slaughter, live weight, weight after bleeding, hot carcass weight and weight of the cannon bone were taken and recorded. The carcasses were then hung on gambrels of standard width and placed in a cool room overnight.

2. Photography and radiography.

Each cooled carcass was photographed from a distance of eight feet prior to taking the carcass measurements. The same gambrel was used for each carcass. After the carcass had been severed into two halves, the cross-section of the longissimus dorsi ("eye muscle") on the fore half of the carcass was photographed using a camera-subject distance of 44 inches. The carcass was photographed both from the dorsal and the lateral (left side) aspect.

In order to get an idea of the distortion caused by hanging on the gambrels overnight, one carcass of each breed type was taken to the X-ray plant and hung so that the fore end of the carcass was in the bail previously used in the other X-raying. Since the carcass was hanging, the aspect was shifted 90 degrees from the previous radiography. The setting used this time was:-

H8 15 MA ½seconds Distance 40 inches

3. Carcass measurements

The measurements on the cooled carcasses included those described by Palsson (1939) and Barton, Phillips and Clarke (1949). The measurements were taken immediately after the photographing of the entire carcass which commenced at about

9:00 A.M. on the day following slaughter.

a) External carcass measurements

These were as follows:-

1) Measurement "F" Leg length, from the deepest point in the crutch to the anterior edge of the distal end of the tarsal.

2) Measurement "G" Maximum width at gigots.

3) Measurement "WR" Maximum width of ribs.

4) Measurement "WF" Maximum width of forequarters.

5) Measurement "WTh" Minimum width behind the scapulae.

6) Measurement "Th" Depth of thorax. This is the maximum depth of the chest behind the shoulders. A measurement was taken on each side and these appear hereinafter as "Th1" and "Th2".

7) Measurement "T" Length of the tibia and tarsus from the tubercle on the proximal end of the tibia to the anterior edge of the distal end of the tarsal.

8) Measurement "R" Length of the radius-ulna from the olecranon process to the styloid process.

9) Measurement "K" Length of the body from the tail head to the base of the neck.

10) Measurement "L" Length of the body from the symphysis pubis to the anterior edge of the middle of the first rib.

11) Measurement "H" Length from the symphysis pubis to the posterior edge of the last rib at the junction with its vertebra.

12) Measurement "P" Length of leg from the symphysis publis to the anterior edge of the distal end of the tarsal.

All the above measurements were taken to the nearest one-tenth of a centimeter. The weight of the cooled carcass was recorded to the nearest one-tenth of a pound.

b) Internal carcass measurements

After the external measurements had been recorded, the carcass was divided into fore and hind halves by cutting transversely between the last thoracic vertebra and the first lumbar vertebra. In cutting, the knife followed the posterior border of the last rib on each side. The fore-end and the hind-end were then weighed separately. The internal measurements were taken on the fore half cross-section exposed by the transverse division. These measurements were recorded to the nearest one-tenth of a centimetre.

The measurements are as follows:-

1) Measurement "A" Length of "eye muscle". This is the maximum distance across the cut surface of the longissimus dorsi from the end next to the spinous process outwards along the rib.

2) Measurement "B" Depth of "eye muscle". This is the greatest distance at right angles to Measurement "A" on the same surface.

3) Measurement "C" Thickness of the subcutaneous fat lateral to Measurement "B".

4) Measurement "D" Depth of fat over the spinous process.

5) Measurement "X" Thickness of muscle layers (mixed with intermuscular fat) on the lower half of the rib, but not including subcutaneous fat.

6) Measurement "Y" Thickness of subcutaneous fat lateral to Measurement "X".

7) Measurement "J" Subcutaneous fat overlying the rib.

4. <u>Dissection of the freshly killed ewes</u>

The dissection of the carcass commenced immediately after the above listed measurements had been taken. Exactly the same procedure was followed as was described for the dissection of the fixed sheep. The bones, muscles and fat were treated and measured in the same manner.

5. Cross-sectioning of the carcasses

Three ewes of each breed were used in this part of the study. The cross-sectioning was done just after the internal carcass measurements had been taken. The procedure was as follows:- The fore end of the carcass was cross-sectioned or cut transversely in a plane parallel to that of the cut that divided the carcass into fore and hind halves. There were six of these parallel sections with the transverse cuts as follows:-

a) Between the eleventh and twelfth thoracic vertebrae.
b) Between the ninth and tenth thoracic vertebrae.
c) Between the seventh and eighth thoracic vertebrae.
d) Between the fifth and sixth thoracic vertebrae.
e) Between the third and fourth thoracic vertebrae.
f) Between the first and second thoracic vertebrae.

As each section was cut, it was photographed from a constant distance of 44 inches so that afterwards a photographic comparison could be made between the two breed types. When the transverse sections included the limb bones, a meat saw was used to sever the bones. It was found that one of the animals had fourteen thoracic vertebrae; hence, the first section removed from that animal included the twelfth, thirteenth and fourteenth thoracic vertebrae instead of the twelfth and thirteenth vertebrae in the normal animal.

6. Measurements on the bones

At the time of dissection only bone weights were taken. Then the bones were labelled and put aside until the dissection work had been completed on all twelve animals.

A number of measurements were made on the bones of the forelimb in order to determine if any major structural difference between breed types was in evidence. The bones measured were:- the left scapulae, the left humerus, the left radius-ulna, the left metacarpus and the thoracic vertebrae. Many of these measurements were the same as those outlined by Barton and Whyte (1952), while the idea for the scapular index was obtained from Sisson (1930).

a) Measurements on the scapula

On the scapulae the following measurements were taken:-

1) Measurement "SA". Distance between the tuber scapulae and the vertebral root of the spine of the scapula.

2) Measurement "SB". Distance from the anterior limit to the posterior limit of the vertebral border.

3) Measurement "SC". Distance from the root of the spine of the scapula to the posterior limit of the vertebral border.

4) Measurement "SD". Distance from the root of the spine of the scapula to the anterior limit of the vertebral border.

5) Measurement "SE". Length from the middle of the glenoid cavity to the vertebral root of the spine of the scapula.

6) Measurement "SF". Length from the middle of the glenoid cavity to the posterior limit of the vertebral border.

7) Measurement "SG". Minimum distance between the anterior edge and the posterior edge of the neck of the scapula.

Measurements "SA" to "SF" were made using a pair of dividers and measuring their spread on a steel rule to the nearest 0.1 centimetre. Measurement "SG" was taken with a pair of sliding calipers that had a vernier scale permitting a reading to 0.01 centimetre.

b) Measurements on the humerus.

The following measurements were made:-

1) Measurement "HA". Length from the most anterior point to the most posterior lateral point.

2) Measurement "HB". Circumference at the mid-point of Measurement "HA". This was taken by circling a very thin wire around the bone, marking it and, after the wire had been straightened, measuring the distance between the marked points to the nearest 0.1 centimetre

on a steel rule. In measuring the circumference of bones, some workers use the position of the nutrient foramen as the guide point. According to Lutkin (1950) this point is not reliable since he found that the position of the nutrient foramina on the shafts of the humeri was so variable that it was not possible to determine one typical position for it. As the Measurement "HB" was to be used in a ratio it was felt that the position of the nutrient foramina should be disregarded.

3) Measurement "HC". The maximum width at Measurement "HB" (lateral side of the bone to the medial side).

4) Measurement "HD". The maximum depth at Measurement "HB" (anterior face of the bone to the posterior face).

Measurement "HA" (to the nearest 0.1 centimetre) was made using the dividers and Measurements "HC" and "HD" (to the nearest 0.01 centimetre) were taken with the sliding calipers.

c) Measurements on the radius-ulna.

The measurements on this bone are as follows:-

1) Measurement "RA". Distance from the most dorsal point and ventral tip of the styloid process.

2) Measurement "RB". Maximum width at mid-point of Measurement "RA". (lateral side of the bone to the medial side)

3) Measurement "RC". The maximum depth at the mid-point of Measurement "RA". (anterior face of the radius to the posterior face of the radius, medial to the ulna).

4) Measurement "RD". Minimum width below the olecranon (anterior edge to the posterior edge).

Measurement "RA" (to the nearest 0.1 centimetre) was made using the dividers and Measurements "RB", "RC" and "RD" (to the nearest 0.01 centimetre) were taken with the sliding calipers.

d) Measurements on the metacarpus ("cannon bone")

1) Measurement "MA". The length from the proximal and to the distal end.

2) Measurement "MB". The circumference at the mid-point of Measurement "MA"

3) Measurement "MC". The width at Measurement "MB" (lateral edge of the bone to the medial edge)

4) Measurement "MD". The depth at Measurement "MB" (anterior face of the bone to the posterior face)

Measurement "MA" was made using the dividers and Measurements "MC" and "MD" were taken with the sliding calipers. Measurement "MB" was made using the thin wire as described for Measurement "HB". Measurements "MA" and "MB" were read to the nearest 0.1 centimetre and Measurements "MC" and "MD" to the nearest 0.01 centimetre.

e) Measurements on the thoracic vertebrae.

In all cases the thoracic vertebrae measured were thirteen in number. The measurements taken were as follows:-

1) Measurement "ThVA". Distance between the anterior aspect of the centrum T.1 (first thoracic vertebra) to the posterior aspect of the centrum of the last thoracic vertebra or T.13. This was taken with a pair of large calipers and read to the nearest 0.1 centimetre.

2) Measurement "ThVB". Greatest vertical height of the spinous processes (excluding the cartilage at the dorsal tips). The base point was the lowest point medial to the transverse processes and lateral to the spinous processes. The point is in a groove that extends the entire length of the thoracic vertebrae The measurement was taken with the use of a 45 degree triangle that had centimetre rulings along one edge. The base of the triangle rode in the above described groove and the height of the dorsal spine of each vertebra was measured. This measurement was to the nearest 0.1 centimetre.

3) Measurement "ThVC". The angles of the dorsal spines. These were measured for each dorsal spine with a transparent protractor whose base rode in the groove described in the measurement of the dorsal heights of the spines. The actual angle measured was the angle between the horizontal plane and the most anterior point on the anterior edge of the dorsal spines as determined by a straight line from the origin of the angle which was at the anterior base of the spine being measured. The reading was to the nearest degree.

4) Measurement "ThVD". Transverse thickness of the dorsal spines. The greatest thickness of the dorsal half of the dorsal spines was measured using the aforementioned sliding calipers. All spines were measured to the nearest 0.01 centimetre.

5) Measurement "ThVE". The posterior-anterior width of the dorsal spines. This is the distance from the posterior edge to the anterior edge of the spinous process at its mid-point in vertical height. This point was marked when the vertical height measurements were made. The width was measured with the sliding calipers and read to the nearest 0.01 centimetre.

SECTION IV

RESULTS.

A. Body Measurements on the Live Animal.

The selection of linear measurements to aid in descriptions and comparisons of the live animal presents a multiple problem. The first part of this problem has to do with the selection of base points that can easily and quickly be located and relocated not only on the same animal but on different animals in the same species. Secondly, having established which measurements are reliable, it is then necessary to discover what they mean in relation to the animal's functional demands and/or meat production in the case of certain domestic animals.

In a previous investigation, Lamont (1934) made the following measurements on the forequarters of Romney sheep:- (1) distance between the shoulder points (lateral tuberosities of the humeri), (2) length of the scapula, (3) breadth of the scapula, (4) length of the humerus, (5) length of the radius-ulna, (6) height at withers, (7) body depth (depth of thorax) and (8) heart girth. Of these he states that little reliance can be placed on the measurements between the shoulder points and the measurements of breadth of scapula.

In a study of accuracy of measurements of sheep Phillips and Stoehr (1945) found that the height at withers, width of shoulders, depth of thorax and the circumference of the chest to be quite dependable.

The measurements taken in this comparison of breed types included the height at withers, heart girth, depth of thorax and width between the lateral tuberosities of the humeri. These, it was felt, were the best possibilities as far as repeatability was concerned. Also the points of measurement to be used were easily located on all animals in this study.

The above body measurements were taken using two different systems of obtaining repeat measures. The first of these will be termed the "Repeatability Trial" and was the system involving three observers each taking the same observation twice. The second system will be known as the "Breed Comparison Test" in which the data were collected by one observer on twelve successive days.

In analysing the data the analysis of variance technique used by Rae (1946) in a similar study was applied. The variance was partitioned to its various sources following the method of Winsor and Clark (1940) as cited by Rae (1946).

1. The repeatability trial

As mentioned before, this type of trial was used by Rae (1946) in order to determine the degree of accuracy that could be expected in making live animal measurements. The procedure involves three observers each taking the same measurement at two different times on the same animal. This trial was made after the animals had been closely shorn in order to reduce error that might result from the fleece. Since the animals had been trained to stand when they had a halter on, the error which might ordinarily be attributed to the animal's "excitability" or "nervousness" was practically eliminated. The means for breed types, observers and repeats are presented in Table 5.

TABLE 5.

MEANS FOR THE MEASUREMENTS IN THE REPEATABILITY TRIAL.

Measurement (Inches)	Breed Type		Observers			Repeats	
	Romney	Cheviot	No. 1	No. 2	No. 3	1st	2nd
Height at withers	22.67	23.21	22.91	23.03	22.87	22.95	22.93
Heart girth	35.04	33.95	34.37	34.47	34.65	34.24	34.75
Depth of thorax	12.45	12.20	12.38	12.23	12.37	12.32	12.33
Width between humeri	8.71	8.46	8.43	8.59	8.74	8.51	8.66

a) The height at withers

This measurement was taken because of the possibility of combining it with the depth of thorax measurement to indicate length of leg in relation to depth of body in the thoracic region.

TABLE 6.

ANALYSIS OF VARIANCE
FOR HEIGHT AT WITHERS.

Source	d.f.	SS	MS	F
Total	119	95.28	-	
Between Sheep	19	74.36	3.91	20.80 **
Between observers	2	0.56	0.28	1.49
Sheep x observers	38	7.55	0.20	1.06
Repeats	1	0.02	0.02	
Repeats x observers	2	1.40	0.70	3.72 *
Repeats x sheep	19	4.24	0.23	1.19
Rpts x obsrvs x shp	38	7.15	0.188	

The analysis of variance of height at withers is shown in Table 6 and the partition of the variance to its various sources is given in Table 7. Differences between sheep are highly significant and account for 72.54% of the total variance. The mean differences between observers and between repeats are small and non-significant which is gratifying from the viewpoint of repeatability of this measurement. Of the interactions the repeats x observers interaction is significant at the 5% level. This indicates that there was no tendency for all observers to measure the height at withers consistently high or consistently low in each repeat. Rather, for example, the tendency was for Observer No. 1 to be high in Repeat No. 1 and to be low in Repeat No. 2, while Observer No. 2 reversed the order in such a way that over both repeats and all observers, the differences averaged out. In general, this interaction does not affect the accuracy of the measurement for practical purposes to the extent that interactions of sheep x observers or sheep x repeats would do, since these latter interactions imply that different observers and different repeats tend to rank the sheep in different orders.

TABLE 7.

PARTITION OF VARIANCE
FOR HEIGHT AT WITHERS.

Source	Components	Value of Components	Value as a %age
Sheep	E + 2SOE + 3RSE + 6SE	(S) 0.613	72.54
Observers	E + 20ROE + 2SOE + 400E	(O)-0.011	-
Repeats	E + 20ROE +3RSE + 6ORE	(R)-0.012	-
Sheep x observers	E + 2SOE	(A) 0.006	0.71
Repeats x observers	E + 20ROE	(B) 0.026	3.28
Repeats x sheep	E + 3RSE	(C) 0.012	1.42
Rps x obsrv x shp	E	(E) 0.188	22.25
	Total	0.845	

SYMBOLS USED IN PARTITION OF VARIANCE.

S is variance in average measurements between sheep.
O is variance in average measurements made by different observers
R is variance in average measurements on different repeats.
A is variance due to interaction between sheep and observers.
B is variance due to interaction between repeats and observers
C is variance due to interaction between repeats and sheep.
E is variance due to triple interaction of repeats, observers and sheep.

b) The heart girth

This measurement was taken because it was thought that the heart girth combined with that of the depth of thorax measurement might give some indication of the shape of the cross-section of the chest.

Table 8 shows that the mean squares between sheep and between repeats are highly significant, while the between observers value is significant. The high variance for sheep indicates that the heart girth measurement can in fact distinguish differences between sheep which, of course, is very essential in the use of this measurement. The analysis also brings out the

TABLE 8.

ANALYSIS OF VARIANCE
FOR HEART GIRTH.

Source	d.f.	SS	MS	F
Total	119	277.02	-	
Between sheep	19	249.29	13.12	62.28 **
Between observers	2	1.63	0.82	4.21 *
Sheep x observers	38	6.08	0.16	
Repeats	1	8.01	8.01	41.08 **
Repeats x observers	2	1.19	0.60	3.08
Repeats x sheep	19	3.41	0.18	
Rpts x obsrvrs x shp	38	7.41	0.195	

fact that the observers tended to measure sheep differently and that the repeats by observers were not entirely consistent. However, the above values may be magnified by the relatively small triple interaction which was used in the test for significance.

TABLE 9.

PARTITION OF VARIANCE
FOR HEART GIRTH.

Source	Symbol for Components	Value of Components	Value as a %age
Sheep	S	2.164	86.25
Observers	O	0.006	0.24
Repeats	R	0.124	4.94
Sheep x observers	A	-0.018	-
Repeats x observers	B	0.020	0.80
Repeats x sheep	C	-0.005	-
Repeats x obsvrs x sheep	E	0.195	7.77
	Total		

The partition in Table 9 shows that the greatest portion of the variance in the heart girth measurement is due to sheep differences and relatively little due to repeats as was suspected in the interpretation of the analysis of variance. The second largest value is that of the triple interaction, but this is still relatively small. On the whole, then, this measurement is sufficiently reliable for use in the present study.

c) The depth of thorax

The measurement was taken because of the possibility of combining it with either the measurement of heart girth to indicate form or with the height of withers to indicate length of leg in relation to depth of body in the thorax region. A further advantage was that the base points used were easily located and stable.

TABLE 10.

ANALYSIS OF VARIANCE
FOR DEPTH OF THORAX.

Source	d.f.	SS	MS	F
Total	119	16.23	-	
Between sheep	19	13.48	0.710	33.81 **
Between observers	2	0.55	0.280	13.33 **
Sheep x observers	38	1.04	0.027	1.29
Repeats	1	0.00	0.000	
Repeats x observers	2	0.09	0.045	2.14
Repeats x sheep	19	0.29	0.015	
Rpts x obsrvrs x shp	38	0.78	0.021	

In this measurement, Table 10 shows the variance between sheep and between observers to be highly significant, the other factors being of small effect. Again, the table of means shows a small difference between the breed types which would indicate a larger difference between sheep. The means for the repeats are very similar but there is a small difference between observers. This shows that each observer, while differing slightly from the others, was able to repeat this measurement with remarkable accuracy.

TABLE 11.

PARTITION OF VARIANCE
FOR DEPTH OF THORAX

Source	Symbol for Components	Value of Components	Value as a %age
Sheep	S	0.1140	78.84
Observers	O	0.0056	3.78
Repeats	R	0.0000	-
Sheep x observers	A	0.0035	2.42
Repeats x observers	B	0.0015	1.04
Repeats x sheep	C	0.0000	-
Rpts x obsrvrs x shp	E	0.0200	13.83
	Total	0.1446	

The apportionment in Table 11 again shows that differences between sheep contribute most to the total variance while the amount contributed by the differences between observers is small. The second largest value is the triple interaction which is composed of the true triple interaction and error not accounted for by the other items in the analysis.

d) The width between the tuberosities of the humeri.

These points were selected since they seemed to be fairly

TABLE 12.

ANALYSIS OF VARIANCE
FOR WIDTH BETWEEN THE TUBEROSITIES OF THE HUMERI.

Source	d.f.	SS	MS	F
Total	119	23.69	-	
Between sheep	19	15.67	0.82	21.59 **
Between observers	2	1.87	0.94	24.74 **
Sheep x observers	38	2.93	0.08	2.11 *
Repeats	1	0.71	0.71	18.68 **
Repeats x observers	2	0.14	0.07	1.84
Repeats x sheep	19	0.89	0.05	1.32
Rpts x obsrvrs x shp	38	1.48	0.038	

easily identifiable on all animals, and because an accurate width measurement might give additional information on the form of the shoulder region.

The analysis in Table 12 shows the F values for between sheep, between observers and between repeats to be highly significant. This indicates that not only did the sheep vary, but so did the observers in taking the measurement and they varied between repeats. The sheep x observers interaction was significant and indicates that the observers failed to rank the sheep in the same order for this measurement.

TABLE 13

PARTITION OF VARIANCE
FOR WIDTH BETWEEN THE TUBEROSITIES OF THE HUMERI.

Source	Symbol for Components	Value of Components	Value as a %age
Sheep	S	0.1217	29.00
Observers	O	0.0207	4.93
Repeats	R	0.2133	50.76
Sheep x observers	A	0.0200	4.76
Repeats x observers	B	0.0015	0.36
Repeats x sheep	C	0.0030	0.71
Rpts x obsvrs x shp	E	0.0400	9.52
	Total	0.4202	

The partition of the variance in Table 13 shows that although there is considerable variance due to the differences between animals, about one-half of the total must be attributed to repeats. Evidently, for the observers concerned, this measurement was not repeated with any high degree of accuracy. The variance actually due to difference between observers is, however, not large. From the findings it can be concluded that this measurement is not as repeatable as might be hoped. The greatest difficulty in taking the reading is in the applying a constant pressure for all animals on the sliding arm of the calipers when it is pushed against the measuring point. Another source of error would be in the sheep's stance. It is necessary that there be the same distance between the two front feet for each measurement. Although the sheep were standing naturally each time, the actual distance could have varied slightly between measurements.

e) A survey of results

A survey of the results for all the measurements by this system reveals a relatively high order of accuracy except for the measurement between the lateral tuberosities of the humeri. Even this last measurement has some merit in that very little interaction appears in the analysis. The apportionment of variance for the height at withers, depth of thorax and for the heart girth showed 72 per cent or more of the variance due to the animals. In all of these cases the second highest value was due to the triple interaction or variance that could not be account for in either the observers, repeats or any of the other interactions.

2. The breed comparison test

In this section attention is focussed on a comparison between the two breeds under consideration. Each measurement was made in two series of six successive days, one series being taken before the animals were shorn and the other after they had been closely shorn in preparation for the photographing and radiographing. Thus, another comparison, that of effect of the fleece upon measurements and their accuracy, was made possible. All the measurements were taken by the same observer in the manner described previously. In the analyses of variance, the comparison of the measurements taken before shearing with those taken after shearing is referred to as "treatments".

a) The height at withers.

The means for this measurement and the analysis of variance appear in Tables 14 and 15.

In the analysis shown in Table 15 the triple interaction

APPENDIX I (continued)

Width between lateral tuberosities of the humeri after shearing (inches)

Sheep No.	1st Repeat	2nd Repeat	3rd Repeat	4th Repeat	5th Repeat	6th Repeat
			Romneys			
5	8.25	8.50	8.50	8.25	8.50	8.75
10	8.75	8.50	8.50	8.50	8.50	8.50
11	8.50	8.00	8.25	8.25	8.25	8.25
23	8.75	9.00	9.00	9.00	8.75	9.00
26	9.25	9.25	9.25	9.00	9.00	9.00
27	8.50	8.25	8.75	9.00	8.50	8.50
R28	8.00	8.00	8.25	8.00	8.25	8.00
35	8.00	7.75	8.00	8.00	7.75	8.00
39	9.00	9.50	9.50	9.25	9.50	9.25
44	7.75	8.25	8.25	8.25	8.00	8.25
Total	84.75	85.00	86.25	85.50	85.00	85.50
Average	8.48	8.50	8.63	8.55	8.50	8.55
			Cheviots			
13	8.75	9.25	8.75	9.00	8.50	9.00
17	8.25	8.25	8.50	8.50	8.25	8.50
18	8.50	8.50	8.25	8.00	8.25	8.00
19	8.50	8.25	8.25	8.25	8.50	8.25
20	8.25	8.25	8.25	8.00	7.75	8.25
24	7.75	8.00	8.00	8.00	8.25	8.25
C28	8.25	8.25	8.00	8.25	7.75	8.00
30	8.25	8.75	8.25	8.25	8.50	8.75
55	7.75	7.75	7.75	7.75	8.00	8.00
68	8.25	8.50	8.25	8.25	8.00	8.25
Total	82.50	83.75	82.25	82.25	81.75	83.25
Average	8.25	8.38	8.23	8.23	8.18	8.33

TABLE 14

MEANS FOR
HEIGHT AT WITHERS.

Treatment (Inches)	Breed Types Romney	Cheviot	Treatment Means
Unshorn	22.77	22.52	22.64
Shorn	22.73	22.77	22.75
Breed Mean	22.75	22.65	

TABLE 15

ANALYSIS OF VARIANCE
FOR HEIGHT AT WITHERS.

Source	d.f.	SS	MS	F
Total	239	269.68		
Between sheep	19	102.18	-	
Between breeds	1	102.18	5.38	3.71 **
Within breeds	18	101.39	5.63	
Between treatments	1	0.79	0.79	
Treatments x sheep	19	20.02	1.05	
Treatments x breeds	1	1.10	1.10	
Within trtmts x breeds	18	18.92	1.05	
Between repeats	5	1.09	0.22	
Repeats x sheep	95	7.45	0.08	
Repeats x breeds	5	3.90	0.78	
Within repeats x breeds	90	3.55	0.04	
Repeats x treatments	5	0.54	0.11	
Rpts x sheep x trtmts	95	137.63	1.459	

term was used to test the three interactions:- treatments x sheep, repeats x sheep and repeats x treatments. These were all found to be non-significant. Hence, the triple interaction was used in testing the repeats, sheep and treatment mean squares. The only term found to be significant was that of sheep which indicates that most of the variance lies in this factor and that little or none of it can be attributed to the repeats, treatments or any of the interactions. In other words, the measurement is very repeatable and the fact that there was two to three inches of wool covering the point of measurement made no difference to results. In testing the significance of breed differences, the within breed term was used. The mean square between breed types was found to be non-significant, indicating that the small difference between the means is due to chance.

b) The heart girth.

The means for the heart girth measurement and the analysis of variance are shown in Tables 16 and 17.

TABLE 16

MEANS FOR
THE HEART GIRTH

Treatment (Inches)	Breed Type Romney	Cheviot	Treatment Means
Unshorn	35.29	33.90	34.59
Shorn	34.26	32.50	33.38
Breed Mean	34.78	33.20	

TABLE 17

ANALYSIS OF VARIANCE
FOR THE HEART GIRTH.

Source	d.f.	SS	MS	F
Total	239	557.84	-	
Between sheep	19	423.23	22.28	
Between breeds	1	148.84	148.84	10.83 **
Within breeds	18	247.40	13.74	
Between treatments	1	88.21	88.21	72.29 **
Treatments x sheep	19	4.99	0.26	3.44 **
Treatments x breed	1	1.92	1.92	
Within treatments x bds.	18	3.07	0.17	
Between repeats	5	3.62	0.72	4.77 **
Repeats x sheep	95	14.42	0.15	1.98 **
Repeats x breeds	5	0.72	0.14	
Within repeats x breeds	90	13.70	0.15	
Repeats x treatments	5	6.10	1.22	15.97 **
Rpts x shp x trtmt	95	7.26	0.076	

In the analysis shown in Table 17 the within breeds terms was used to test for any difference between breeds. The triple interaction was used to test the repeats x treatments, repeats x sheep and the treatments x sheep interactions, all of which proved to be significant. In order to test the treatment mean square, the repeats x treatment factor was utilized. In testing the repeats, the repeats x sheep term was used.

In this measurement the differences between breed types, between treatments and between repeats were found to be significant. The table of means (Table 16) shows that the Romney group has the larger heart girth both before and after shearing. The shearing made an average difference of about 1.2 inches when compared with the same group in the unshorn condition. This is quite feasible in that in making the measurement the flexible steel was against the skin or wool of the sheep for the whole measurement. Any wool present would tend to increase the heart girth measurement as the tape could not be drawn up to the actual surface of the skin.

c) The depth of thorax

The means for the depth of thorax and the analysis of variance for this measurement appear in Tables 18 and 19.

TABLE 18.

MEANS FOR
THE DEPTH OF THORAX.

Treatment (Inches)	Breed Romney	Type Cheviot	Treatment Means
Unshorn	12.43	12.16	12.30
Shorn	12.33	12.06	12.20
Breed Mean	12.38	12.11	

In the analysis shown in Table 19 the triple interaction was first used to test the repeats x sheep, the repeats x treatments and the treatments x sheep mean squares. In this it was found that only the repeats x treatments interaction was signi-

TABLE 19.

ANALYSIS OF VARIANCE
FOR DEPTH OF THORAX.

Source	d.f.	SS	MS	F
Total	239	31.00	-	
Between sheep	19	20.65	1.09	24.99 **
Between breeds	1	4.27	4.27	4.69 *
Within breeds	18	16.39	0.91	
Between treatments	1	0.55	0.55	5.26
Treatments x sheep	19	1.13	0.06	1.51
Treatments x breeds	1	0.00	0.00	
Within treatments x bds	18	1.12	0.06	
Between repeats	5	0.28	0.06	
Repeats x sheep	95	4.13	0.04	1.11
Repeats x breeds	5	0.55	0.11	
Within repeats x breeds	90	3.58	0.03	
Repeats x treatments	5	0.52	0.10	2.67 *
Repeats x sheep x trtmts	95	3.74	0.039	

ficant. It, in turn, was used to test the treatment mean square which proved to be non-significant. It was also used on the repeats mean square with the same result. To test the sheep mean square the triple interaction was used and a highly significant result obtained. The within breeds term was again used to test the between breeds factor. This showed that the Romney group averages significantly deeper in the thorax. Since the difference due to treatment was non-significant it is apparent that the measurement can be taken satisfactorily on the unshorn animal.

d) The width between the tuberosities of the humeri.

The means and analysis of variance for this measurement will be found in Tables 20 and 21.

This time the triple interaction was used again to test the treatments x sheep, the repeats x sheep and the repeats x treatments interactions. Of these, the last two were significant. To test the mean square for sheep, the treatment x sheep value was used and showed it to be highly significant. The

TABLE 20.

MEANS FOR
THE WIDTH BETWEEN THE LATERAL TUBEROSITIES OF THE HUMERI.

Treatment (Inches)	Breed Type Romney	Cheviot	Treatment Means
Unshorn	8.65	8.59	8.62
Shorn	8.53	8.26	8.40
Breed Means	8.59	8.43	

TABLE 21.

ANALYSIS OF VARIANCE
FOR WIDTH BETWEEN THE LATERAL TUBEROSITIES OF THE HUMERI.

Source	d.f.	SS	MS	F
Total	239	50.16	-	
Between sheep	19	34.30	1.81	18.48 **
Between breeds	1	1.71	1.71	
Within breeds	18	32.50	1.81	
Between treatments	1	3.07	3.07	18.90 **
Treatments x sheep	19	1.86	0.10	2.30 **
Treatments x breeds	1	0.54	0.54	
Within treatments x bds	18	1.32	0.07	
Between repeats	5	0.79	0.16	
Repeats x sheep	95	5.30	0.06	1.31
Repeats x breeds	5	0.59	0.12	
Within repeats x breeds	90	4.71	0.05	
Repeats x treatments	5	0.81	0.16	3.83 **
Repeats x sheep x trtmts	95	4.04	0.043	

repeats x treatments term was used to test treatments and repeats, and, of these, only the between treatment mean square was of a significant magnitude. To check for breed difference the within breeds term was used as the testing term. No breed type difference was in evidence. The high significance of the treatment mean square indicates that the measurement after shearing was significantly less than the same measurement on the unshorn animals.

e) A survey of results.

A survey of the results in this section shows in every case that differences between sheep were significant and important. However, only in two of the measurements, depth of thorax and heart girth, was a breed type difference indicated. In both these cases, the Romney group was the larger by 1.5 inches in heart girth and by about 0.25 inches in the depth of thorax.

Treatment exerted an effect only in the heart girth and in the depth of thorax measurement but only in the former was the difference appreciable.

The measurements taken were all satisfactorily repeatable as evidenced by the non-significant mean squares for repeats in all but the heart girth measurement. In this one as with the rest, a partition of variance showed either a very small or a nil value. With some prior practice on these measurements, one observer can take them quite accurately even with two or three inches of wool on the animal. When wool to that extent is on the sheep, only the heart girth measurement is affected to any great degree.

The breed type means, Standard Deviation and Standard Error are tabulated in Table 22. These are the means obtained from the measurement of the sheep when shorn.

TABLE 22.

MEANS FOR
THE LIVE ANIMAL MEASUREMENTS.

Measurement	Breed Type	Mean (Inches)	S.D.	S.E.
Height at Withers	Romney	22.73	0.67	0.21
	Cheviot	22.77	0.79	0.25
The heart girth	Romney	34.26	0.81	0.26
	Cheviot	32.50	0.77	0.24
Depth of thorax	Romney	12.33	0.15	0.05
	Cheviot	12.06	0.29	0.09
Between humeri	Romney	8.53	0.16	0.05
	Cheviot	8.43	0.21	0.07

f) Ratios using the live animal measurements.

In order to get some idea of the form of the forequarters from the means as given above it is necessary to use them in ratios or proportions.

The first and most obvious ratio is the proportion of the height at withers that is taken up in body depth. It might be represented as the length of leg in relation to depth of body. It is calculated by taking the mean depth of thorax measurement as a percentage of the height at withers. For the Romney group this is 54.2 per cent and for the Cheviot types it is 52.9 per cent. This difference of 1.3 per cent is not appreciable and should not be considered as a real one for these groups.

The next ratio considered is a shoulder blockiness proportion which combines the averages for the depth of thorax and the width between the humeri. Using this last measurement as a percentage of the depth of thorax might show one type to be the more blocky in this region. For the Romney group this percentage is 69.2 and for the Cheviot group 69.8. Again, there is no noticeable difference.

A third possibility insofar as ratios are concerned is a shape of thorax index which can be calculated by using the depth of thorax measurement in combination with the heart girth measurement. With depth of thorax expressed as a percentage of heart girth, the Romney figure is 36.0 per cent and for the Cheviot group it is 37.1 per cent. A small percentage in this calculation would indicate a more circular thorax and a larger one would mean a more oval type. In this connection, an interesting theory has been worked out by Stockard (1941) in his experiments on form and behaviour in the canine. He was able to classify a lethargic type and a more active type of dog by considering their form. The Bassethound is a short legged animal with a round thorax and tends to become fat easily, while, in contrast, the German Shepherd has long, thin legs and a thin thorax and abdominal region and is an active type. Although no real differences were discovered between the two breed types

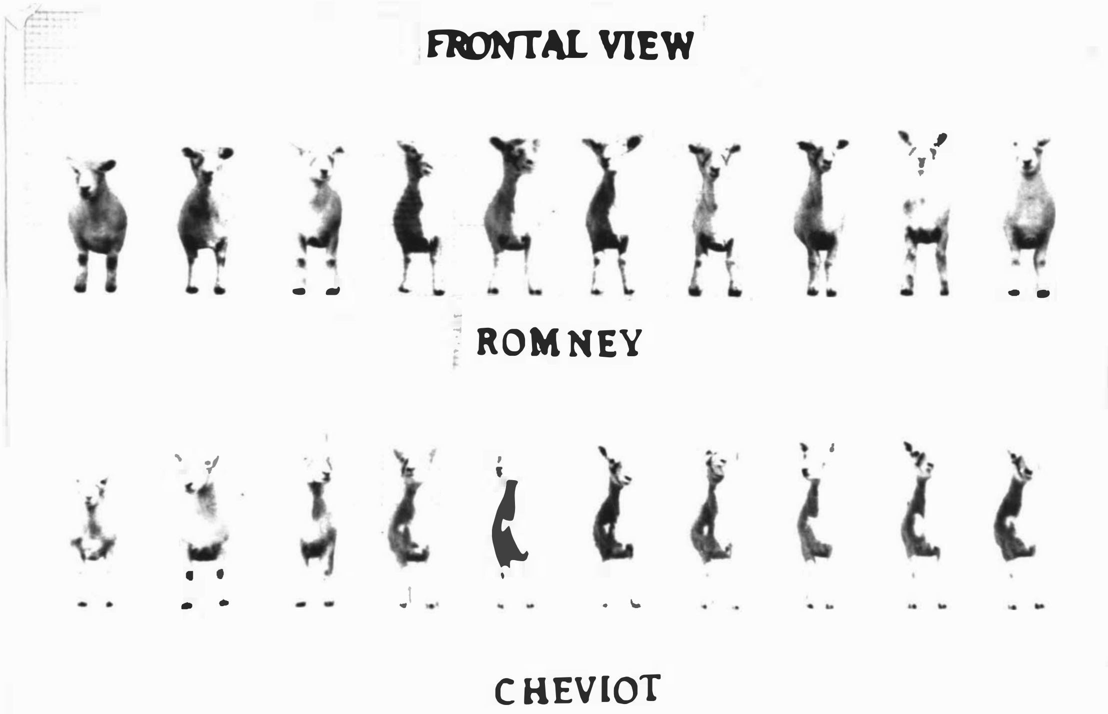


Fig. 14.--Frontal View of the Live Animals

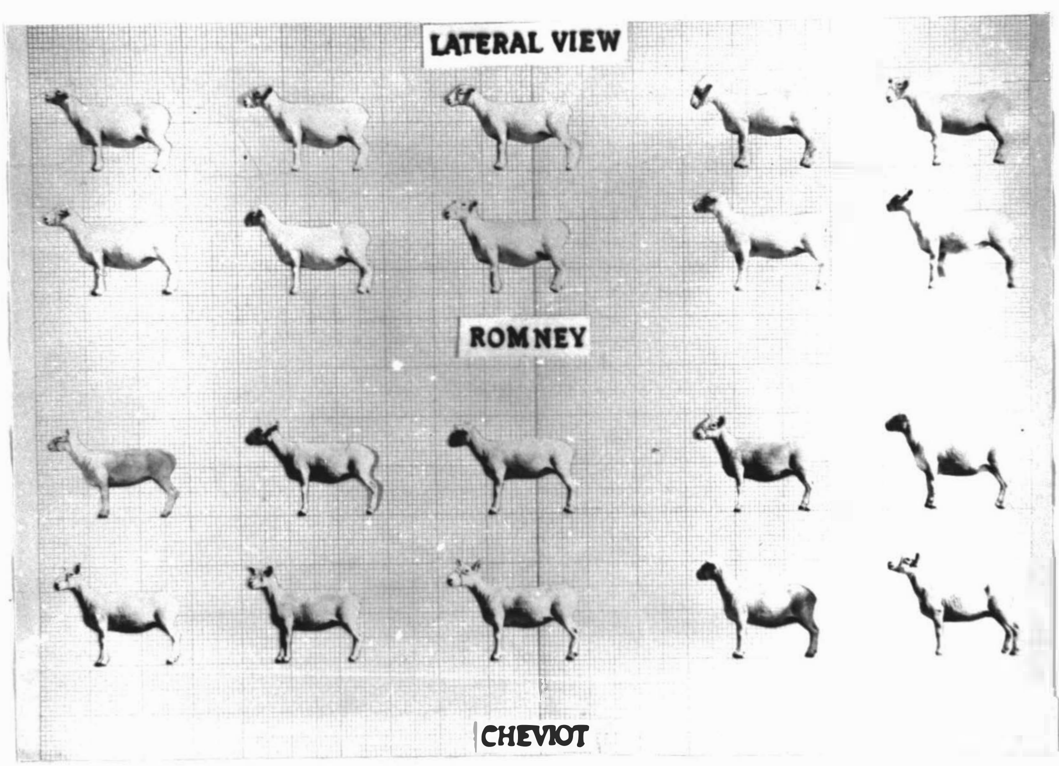


Fig. 15.--Lateral View of the Live Animals

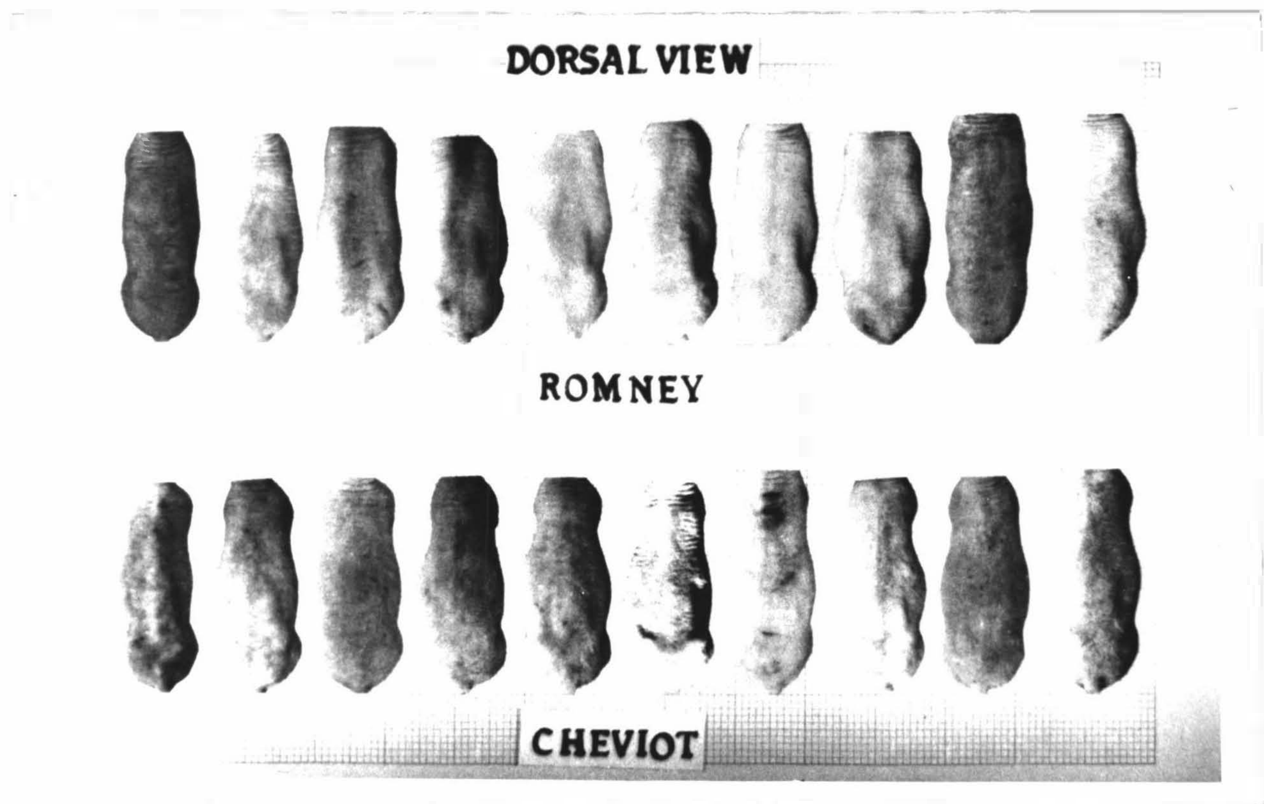


Fig. 16.--Dorsal View of the Live Animals

under consideration with respect to this aspect of form, a further study with more contrasting breed types could very easily bring up such a correlation in the sheep.

A photographic comparison of the frontal, lateral and dorsal views of the two breed types appears in Figures 14, 15 and 16.

3. Live animal measurements and the same measurement on the fixed ewes.

Each measurement that had been taken on the live animals was applied to the same animals after they had been fixed with the formal saline solution. For purposes of comparison, the average live measurements of each animal fixed was taken from the series of six repeats on the shorn animal by one observer, as it was the same observer that repeated these measurements on the fixed animals. The same procedure as described previously was followed in taking the measurements. On the fixed animals, each measurement was repeated three times and the average of these taken. It was found that on the fixed animal the base points were very stable and hence there was practically no difference between repeats. The measurements did not vary more than 0.25 inches between repeats.

TABLE 23.

MEANS SHOWING
EFFECT OF FIXING ON LIVE MEASUREMENTS (INCHES)

Animal	Height at Withers		Heart Girth		Depth of Thorax		Width Between Humeri.	
	Live	Fixed	Live	Fixed	Live	Fixed	Live	Fixed
20	22.63	22.83	31.50	34.75	11.75	12.08	8.13	8.08
24	23.29	23.83	32.38	34.75	12.21	12.25	8.04	7.67
68	22.46	22.75	31.42	33.42	11.83	12.00	8.25	8.00
10	23.96	23.67	33.25	35.42	12.13	12.58	8.54	8.50
23	22.29	23.67	35.00	35.58	12.54	12.75	8.92	8.50
R28	21.50	22.67	33.83	35.50	12.21	12.58	8.08	8.08
Average	22.50	23.24	32.89	34.90	12.11	12.37	8.33	8.14

A comparison of the averages in Table 23 would be legitimate, because in every case, with the exception of one, the change in each measurement on each animal from the live state to the fixed condition was in the same direction. From a review of the averages it will be noted that in the fixed state there was a slight increase in the height at withers and in the depth of thorax, and quite an appreciable increase in the heart girth measurement. In the distance between the lateral tuberosities of the humeri there was a slight decrease which is natural in view of the body position of the animals while undergoing fixation.

4. Shoulder moulds

As mentioned in Section IIIC, the reason for taking the moulds of the shoulder was to obtain a general indication of the form of the cross-section through the shoulder region of the living animal. Photographs of these moulds appear in Figure 17, so that a visual comparison may be obtained.

Only two measurements will be considered in this section:-

a) Area. The area of the cross-section in square centimetres obtained by the use of the planimeter.

b) Base distance. The distance between the lateral tuberosities of the radii.

The mean differences between breeds with standard deviations, standard errors and t values are shown in Table 24.

TABLE 24.

MEASUREMENTS
OF SHOULDER MOULDS.

Measurement	Breed Type	d.f.	Mean	S.D.	S.E.	t
Area (sq.cm.)	Romney	9	455.8	54.4	17.2	1.14 NS
	Cheviot	9	448.3	38.1	12.1	<0.3
Base distance (cm)	Romney	9	21.7	1.96	0.62	2.06 NS
	Cheviot	9	20.3	0.88	0.28	<0.1

The means in the comparisons of Table 24 show the Romney group to be the larger in both measurements. However, in area the difference is small and non-significant as shown by a t test.

With the second measurement, although the means are quite close together, the standard deviation is relatively small and the difference is just short of being significant.

In order to determine whether there was any difference in these measurements between the live animals and the same animals when fixed with the formal saline solution, an analysis of variance test was applied to these data. This and the means appear in Tables 25 and 26.

TABLE 25.

MEANS FOR
SHOULDER MOULD MEASUREMENTS.

Measurement	Breed Type		Treatment		S.E.
	Romney	Cheviot	Live	Fixed	
Area (sq.cm.)	497.6	470.5	434.0	534.1	9.56
Base distance (cm)	21.4	18.5	21.1	18.8	0.52

TABLE 26.

ANALYSES OF VARIANCE
FOR SHOULDER MOULD MEASUREMENTS.

Source	d.f.	SS	MS	F
		For Area		
Total	11	37797	-	
Between treatments	1	30100	30100	54.92 **
Between breeds	1	2214	2214	4.04
Interaction	1	102	102	
Error	8	4381	548	
		For Base Distance		
Total	11	55.4	-	
Between treatments	1	16.6	16.6	10.18 *
Between breeds	1	25.3	25.3	15.52 **
Interaction	1	0.5	0.5	
Error	8	13.0	1.63	

In the comparison between the breed types the same holds as for the results of the _t_ test between breed types. However, in this instance, the base measurement is significantly greater in the Romney group.

Since, in the breed comparisons, the base distance was significantly longer in the Romneys with little difference in area, it is apparent that a difference of form exists. This will be noted by comparing the photographs of the moulds in Figure 17.

Treatment effects show up significantly in each case. In area, the fixed group is larger, the difference being highly significant. In the base measurement, treatment exerted the effect of shortening the measurement somewhat. The fact that the animals, while being fixed, were on their side is the probable explanation for this occurrence. The data for area indicates that during the fixing treatment a certain amount of swelling took place.

In order to see if any relationship existed between the area of the shoulder mould and the base distance, the correlation coefficient between the two variables in each breed type was calculated on the live animal moulds. It is shown in Table 27.

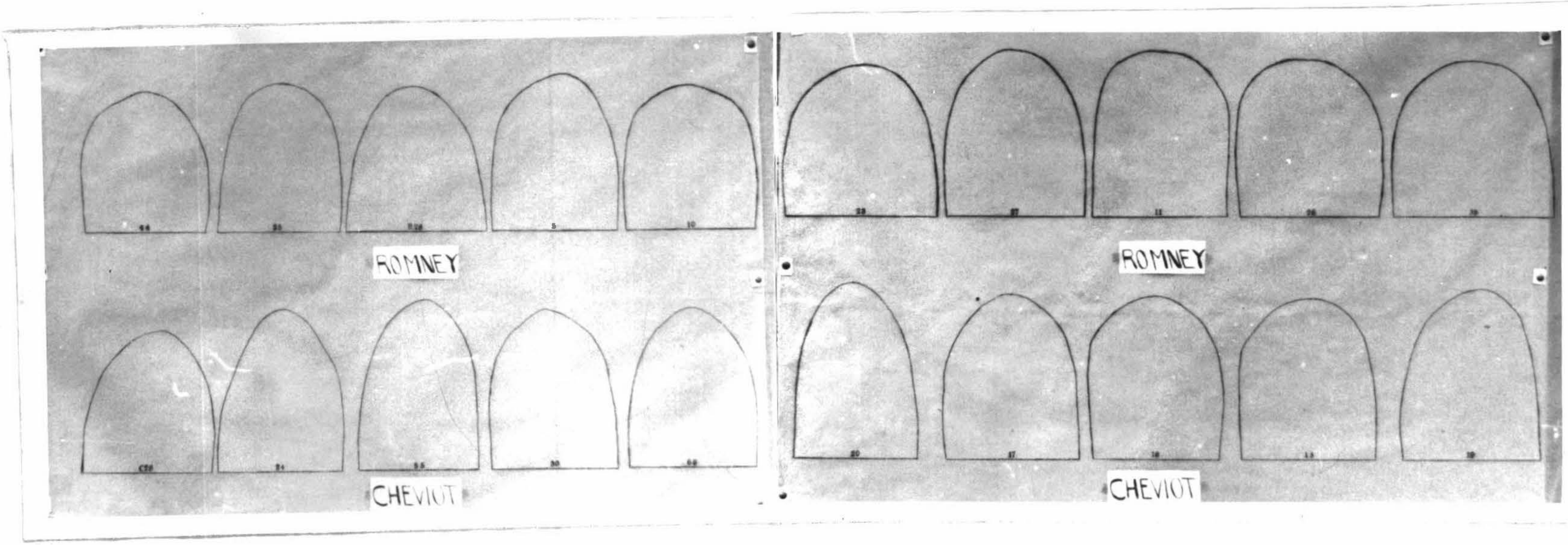
TABLE 27

CORRELATION COEFFICIENTS
FOR BASE DISTANCE WITH AREA OF SHOULDER MOULDS.

The Correlation	Pairs	Romney	Cheviot
Base distance with area of shoulder mould	10	+0.769 **	+0.546 NS

The correlation coefficient necessary for significance at the 5% level is 0.602.

The results in Table 27 show that in the Romney type, when the basal distance (distance between the lateral tuberosities of the radii) increases, so does the area of the shoulder cross-section. In other words, the form or shape remains relatively constant in the Romney group no matter what the size of the animal. The Cheviot group shows a trend in this direction but since the correlation coefficient is not quite at the significant level, it must be concluded that the



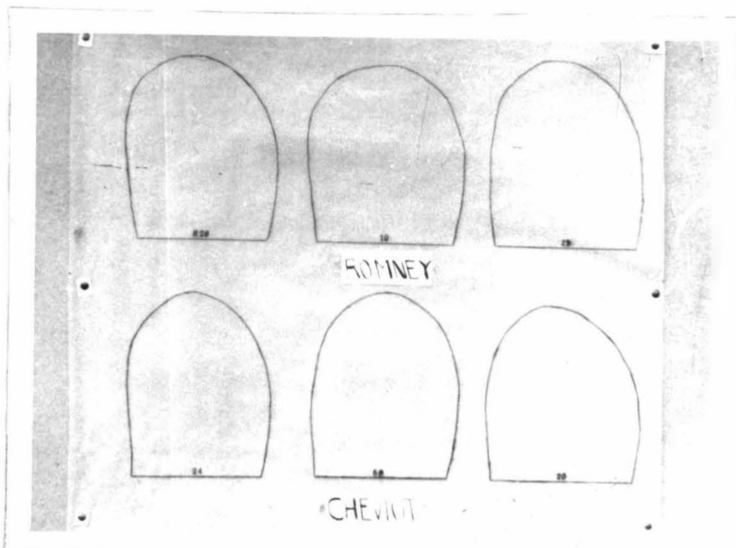


Fig. 17.--Photographs of the shoulder moulds. Above, the shoulder moulds taken on the live animals and; left, the shoulder moulds taken on the formal saline fixed group after fixing.

shape is more variable in the Cheviot group. This is apparent in the photographs of the moulds.

5. Weights

The following weights were taken:- live weights, weights of the fixed animals, slaughter weights and weights of the carcasses.

a) Live weights.

All animals including those which were formalin fixed were weighed prior to slaughter. As mentioned before, this weighing was preceded by about a ten hour starvation period. The means of these weights with standard deviations and standard errors are shown in Table 28.

TABLE 28.

LIVE ANIMAL WEIGHTS.

Breed type	d.f.	Mean (Pounds)	S.D.	S.E.	t
Romney	8	104.7	11.9	3.97	1.30 NS
Cheviot	8	98.6	7.5	2.50	<0.3

Although the means differ by about six pounds, the variability within the groups is very high as evidenced by the large standard deviation. A t test shows that the difference between the means is non-significant. This is indeed fortunate, since it means that the groups under study can be compared directly without necessitating any correction for differing body weights.

b) Live weight as compared with fixed weight.

The average weight of all the formalin fixed animals just prior to fixing was 107.6 pounds. This average is high because in the random allocation to each treatment it so happened that the heaviest animals in each breed type were allotted to this treatment. The average weight of the fixed animals on the day following fixation was 111.2 pounds. This increase of three and one-half pounds occurred consistently in all sheep and must be attributed to the surplus weight of the formal saline injected over the weight of the blood which it replaced.

c) Slaughter weights.

This weight was taken on the six animals of each breed type that were slaughtered in the ordinary manner. It includes:- live weight just prior to slaughter, bled weight just prior to skinning (including the weight of head and internal organs), hot carcass weight (with kidneys left in the carcass) and cold carcass weight (taken after the carcasses had hung in the cooler overnight for a period of twelve to fourteen hours). Table 29 shows the analyses of these data, the differences between the means being tested by the t test.

TABLE 29.

MEANS, ETC.
FOR SLAUGHTER WEIGHTS.

Weight	Group	d.f.	Mean (Pounds)	S.D.	S.E.	t
Live weight	Romney	5	100.9	11.5	4.7	0.79 NS
	Cheviot	5	96.5	7.9	3.2	<0.5
Bled weight	Romney	5	95.7	11.0	4.5	0.75 NS
	Cheviot	5	91.6	7.6	3.1	<0.5
Hot carcass weight (With kidneys)	Romney	5	50.7	8.4	3.4	0.45 NS
	Cheviot	5	49.0	3.6	1.5	
Cold carcass weight (With kidneys)	Romney	5	49.7	8.4	3.4	0.46 NS
	Cheviot	5	48.0	3.6	1.5	

The means in Table 29 show the Romney group to be slightly heavier in all cases, but in each case the standard deviation is so large (especially in the Romney) that this difference is not significant. However, it will be noted that the difference narrows slightly from the live weight averages to the bled weight averages and still more from the bled weight averages to the hot carcass weight. This could be due either to a little larger head or a little greater weight of the internal organs or in the weight of the contents of the alimentary tract in the Romneys. Considering the change from the hot carcass weight to the cold carcass weight, it will be seen that each group averages a loss of 1.0 pounds in the overnight cooling process. This loss represents 1.97 per cent of the average live weight in the Romney ewe group and 2.04 per cent in the group of Cheviot ewes. This loss is similar to that quoted by Barton (1952b) who found that in 88 Romney ewe lambs the overnight loss in the same cooler was 2.51 per cent. The small difference between the percentage losses might be explained by the fact that the animals in this study were mature ewes and that their period in the cooler was about three to five hours less than the carcasses studied by Barton. According to Barton (1952a), the above loss is due mainly to evaporation and seems to be less in animals carrying more fat. Although it was found later in the dissections that the Romney group carried more fat, this did not affect the loss to any real degree.

The dressing percentage calculated by expressing hot carcass weight as a percentage of the live weight is 50.25 for the Romney group and 50.78 for the Cheviot types. Again, no marked difference is apparent.

d) Weight of the carcass sections.

After the cooled carcass had been weighed and measured, it was halved by cutting through between the last thoracic vertebra and the first lumbar vertebra. The two resulting parts were weighed. The means and analyses appear in Table 30.

As in the case of carcass weight, the Romney group means are slightly larger although still not significantly so. The standard deviations are still a little over twice as high in the Romney group as compared with the Cheviot group. The totals of the two parts are exactly the same as previously found for the cold carcass weights indicating that the weight measurements are devoid of any inaccuracies.

A term sometimes used by Cheviot breeders has to do with the "balance" or equality of the hind and fore ends of the

TABLE 30.

WEIGHTS OF CARCASS SECTIONS.

Weight	Group	d.f.	Mean (Pounds)	S.S.	S.E.	t
Weight of hind quarters	Romney	5	23.0	4.4	1.8	0.31 NS
	Cheviot	5	22.4	1.7	0.7	
Weight of fore quarters	Romney	5	26.7	4.1	1.7	0.54 NS
	Cheviot	5	25.7	1.9	0.8	
Total weight	Romney	5	49.7	8.4	3.4	0.46 NS
	Cheviot	5	48.0	3.6	1.5	

animal. The proportion of the fore-end to the hind half was calculated to see whether differences in "balance" existed between the breed types. The ratio of the anterior half of the carcass to the posterior end (using the above means) proved to be 1 : 0.86 for the Romney group and 1 : 0.87 for the Cheviot group, showing that there was little difference between the two samples.

B. Carcass Measurements.

1. External carcass measurements.

The external carcass measurements can be divided into two major groups, the leg measurements and the body measurements.

a) The leg measurements.

The leg measurements that were taken on the twelve carcasses are as follows:- "F" (leg length), "T" (length of tibia and tarsus), "R" (length of the radius-ulna) and "P" (distance between the symphysis pubis and tarsus). More details concerning these measurements will be found in Section IIIG. The means and analyses for these measurements are shown in Table 31.

TABLE 31.

CARCASS LEG MEASUREMENTS.

Measurement	Group	d.f.	Mean (cm)	S.D.	S.E.	t
"F"	Romney	5	28.8	0.73	0.30	3.58 **
	Cheviot	5	27.3	0.72	0.29	
"T"	Romney	5	20.3	0.97	0.40	0.49 NS
	Cheviot	5	20.0	0.32	0.13	
"R"	Romney	5	19.2	0.59	0.24	0.36 NS
	Cheviot	5	19.1	0.34	0.14	
"P"	Romney	5	37.7	1.37	0.56	1.42 NS
	Cheviot	5	36.4	0.72	0.29	

In the data shown in Table 31 the Romney types have a greater mean length for all measurements. The "F" measurement is the only one in which this difference is marked, the t value being significant at the one per cent level of probability. Since "F" is governed to a large extent by the amount of muscle and fat present in the crutch (Barton et al, 1949), the logical conclusion would be that the average animal in the Cheviot group is better filled in the crutch.

b) The body measurements.

1) Width measurements of the carcass.

The measurements of width, which have been described in Section IIIG, are as follows:- "G" (width of gigots), "WR" (width of ribs), "WF" (fore-quarters width), "WTh" (width of trunk posterior to the scapulae) and "Th" (thorax depth). The data for depth of thorax and its repeat on the opposite side of the carcass were analysed separately and appear in Table 32 as "Th1" and "Th2".

TABLE 32.

CARCASS WIDTH MEASUREMENTS.

Measurement	Group	d.f.	Mean (cm)	S.D.	S.E.	t	
"G"	Romney	5	27.9	0.95	0.39	0.80	NS
	Cheviot	5	28.5	2.46	1.00		
"WR"	Romney	5	26.6	1.71	0.70	0.41	NS
	Cheviot	5	27.0	3.99	1.63		
"WF"	Romney	5	19.3	1.11	0.45	1.77	NS
	Cheviot	5	20.2	0.45	0.18		
"WTh"	Romney	5	18.2	1.13	0.46	0.36	NS
	Cheviot	5	18.4	0.72	0.29		
"Th1"	Romney	5	30.3	0.99	0.40	0.16	NS
	Cheviot	5	30.2	1.11	0.45		
"Th2"	Romney	5	30.3	0.92	0.38	0.41	NS
	Cheviot	5	30.1	0.78	0.32		

In width measurements, the Cheviot group has a slightly higher mean except for the two depth of thorax measurements. In four of the measurements shown in Table 32 the difference is not more than 0.4 centimetres and in the other two ("WF" and "G") the difference is less than one centimetre. In none of the measurements is the difference even close to being significant. It is interesting to note that in the measurements of width of gigots and of width of ribs, the Cheviot types show more than twice the variability shown by the Romneys, and that this variability is relatively high as compared with variabilities of the rest of the width measurements in either breed type. The means for the depth of thorax are in the same direction as that observed in the depth of thorax measurements on the live animals.

2) Length measurements.

In this section, the three measurements considered are:- "K" (body length from tail head to the base of the neck), "L" (distance between the first rib and the symphysis pubis), and "H" (distance from the last rib to the symphysis pubis). The pertinent data are found in Table 33.

TABLE 33.

CARCASS LENGTH MEASUREMENTS.

Measurement	Group	d.f.	Mean (cm)	S.D.	S.E.	<u>t</u>
"K"	Romney	5	67.3	3.56	1.45	1.75 NS
	Cheviot	5	64.5	1.58	0.64	<0.2
"L"	Romney	5	66.4	2.52	1.03	0.98 NS
	Cheviot	5	65.3	1.21	0.49	<0.4
"H"	Romney	5	34.2	1.54	0.63	1.11 NS
	Cheviot	5	33.4	0.86	0.35	<0.3

The means for the length measurements in Table 33 show the Romney group to be slightly longer than the Cheviot group. However, this difference is small and statistically non-significant. Considering these measurements in relation to the ones for the width where the Cheviot groups had the higher means one might say that in the groups under study, the Romney type carcasses were proportionately longer and narrower while the Cheviot type carcasses were proportionately more compact.

c) Correlation of certain carcass measurements with live animal measurements.

In order to determine if any relationship existed between the "WF" measurement on the carcass and the width between the tuberosities of the humeri on the live animal, the correlation coefficient between the two was calculated. In the calculation the average of the six live animal measurements taken by one observer on the shorn animals were correlated with width of the shoulder measurements ("WF") on the carcasses of the same animals. Also, the correlation coefficient was calculated for the measurement of depth of thorax on the live animal and the depth of thorax measurement ("Th") on the carcass of the same animal. In order to do this the two depth of thorax measurements ("Th1" and "Th2") were averaged, as were the six live animal measurements for each sheep. The results are shown in Table 34.

TABLE 34.

CORRELATION COEFFICIENTS
FOR CERTAIN LIVE ANIMAL MEASUREMENTS WITH CARCASS MEASUREMENTS.

Correlation	Pairs	r
"WF" with width between tuberosities of humeri	12	+0.755 **
"Th" with depth of thorax	12	+0.862 **

The correlation coefficient necessary for the one per cent level of significance is 0.684.

Thus it is found that these two measurements on the carcass are highly correlated with the two corresponding live animal measurements.

A photographic comparison of the carcasses from both the lateral and dorsal aspect appears in Figures 18 and 19.

2. Internal carcass measurements.

Measurements on the posterior face of the fore half of the carcass which was exposed by the transverse division previously described have been used by a number of workers to estimate and appraise the meat qualities of sheep. Hirzel (1939) and Palsson (1940) have used these measurements in estimating the amounts of muscle and fat in the carcasses of lambs. Barton et al (1940) have used them in comparing the carcass quality of lambs of "poor quality" sires with the progeny of "good quality" rams. However, no published data on this sub-

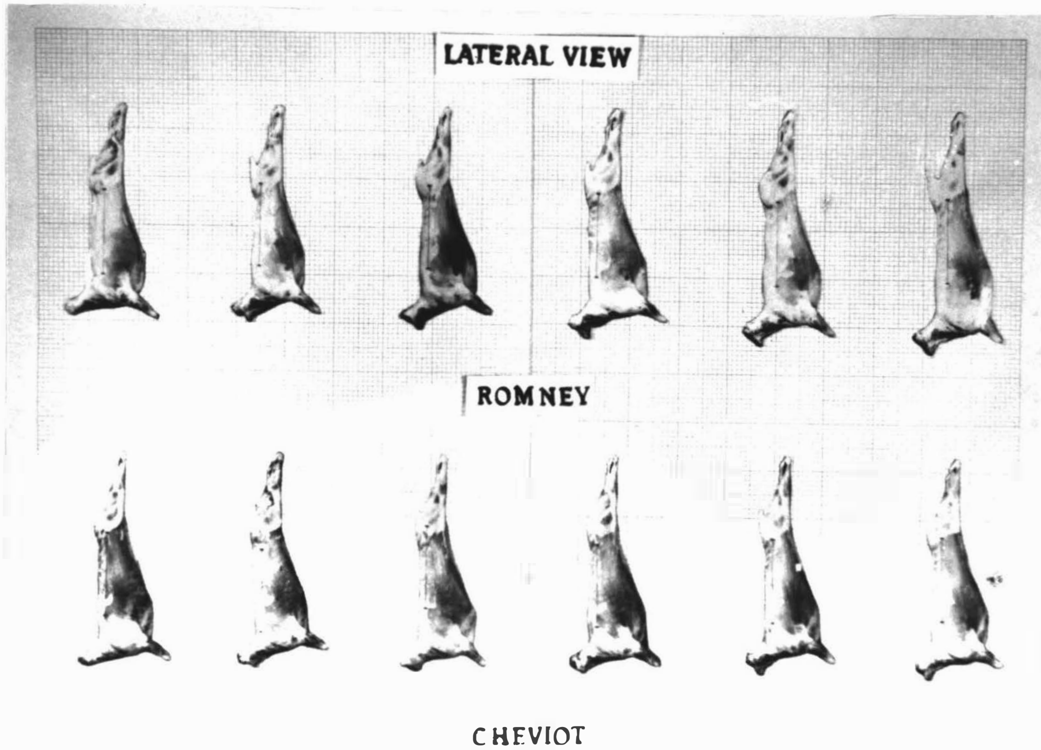


Fig. 18.--Lateral View of the Carcasses

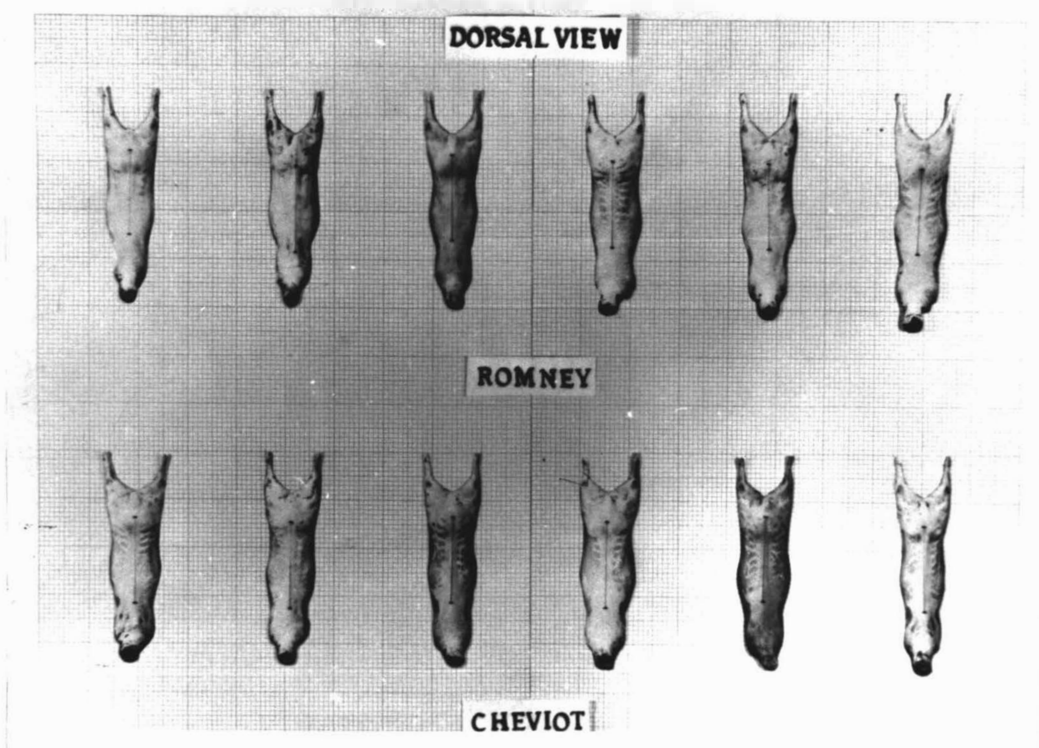


Fig. 19.--Dorsal View of the Carcasses

ject was found for mature sheep.

a) Measurements of muscle development.

The internal muscle measurements include:- "A" (length of "eye"muscle"), "B" (depth of "eye muscle"), and "X" (thickness of muscles plus intermuscular fat on the lower half of the rib). The analyses for the measurements and their means are shown in Table 35.

TABLE 35.

MEASUREMENTS OF MUSCLE DEVELOPMENT.

Measurement	Group	d.f.	Mean (mm)	S.D.	S.E.	t
"A"	Romney	5	57.3	4.8	1.96	3.13 *
	Cheviot	5	64.5	2.7	1.10	
"B"	Romney	5	30.7	3.3	1.35	0.46 NS
	Cheviot	5	30.0	1.7	0.69	
"X"	Romney	5	16.7	1.5	0.61	2.00 NS
	Cheviot	5	18.7	2.0	0.82	<0.2

The means in Table 35 show that the Cheviot type has a longer "A" measurement and therefore greater broadness in the m. longissimus dorsi. There is a difference of about seven millimetres between the averages for the groups and this is significant at the five per cent level of probability. The means for the depth of muscle (measurement "B") are reversed from the order found for the "A" measurement. The Romney group has a slightly greater average depth, though this difference is non-significant. Thus, when the B/A x 100 ratio (shape index) as applied by Hirzel (1939), Walker and McMeekan (1944) and others is used, it is noted that the average Romney of this group will have an "eye"muscle" tending toward the circular while the average Cheviot type has an "eye muscle" whose shape (in the same cross-section) tends toward the oval or elliptical.

b) Measurements of fat development.

The internal fat measurements include:- "C" (thickness lateral to "B"), "D" (depth over dorsal spinous process), "Y" (lateral depth over "X") and "J" (thickness of subcutaneous fat over the rib). The analyses for these measurements and their means appear in Table 36.

TABLE 36.

MEANS FOR
MEASUREMENTS OF FAT DEVELOPMENT.

Measurement	Group	d.f.	Mean (mm)	S.D.	S.E.	t
"C"	Romney	5	3.3	1.75	0.71	1.35 NS <0.2
	Cheviot	5	2.2	1.17	0.48	
"D"	Romney	5	3.0	0.51	0.21	0.98 NS <0.4
	Cheviot	5	2.3	1.67	0.68	
"Y"	Romney	5	2.2	0.98	0.40	0.86 NS <0.5
	Cheviot	5	1.7	1.02	0.42	
"J"	Romney	5	6.2	2.32	0.95	0.11 NS
	Cheviot	5	6.0	2.48	1.01	

In none of the fat measures shown in Table 36 is there a significant breed type difference. However, the Romney group mean is higher in all instances. As will be noted from the standard deviations, the variability within breed types is high.

A photographic comparison of all cross-sections from which the above internal measurements were taken appears in Figure 20.

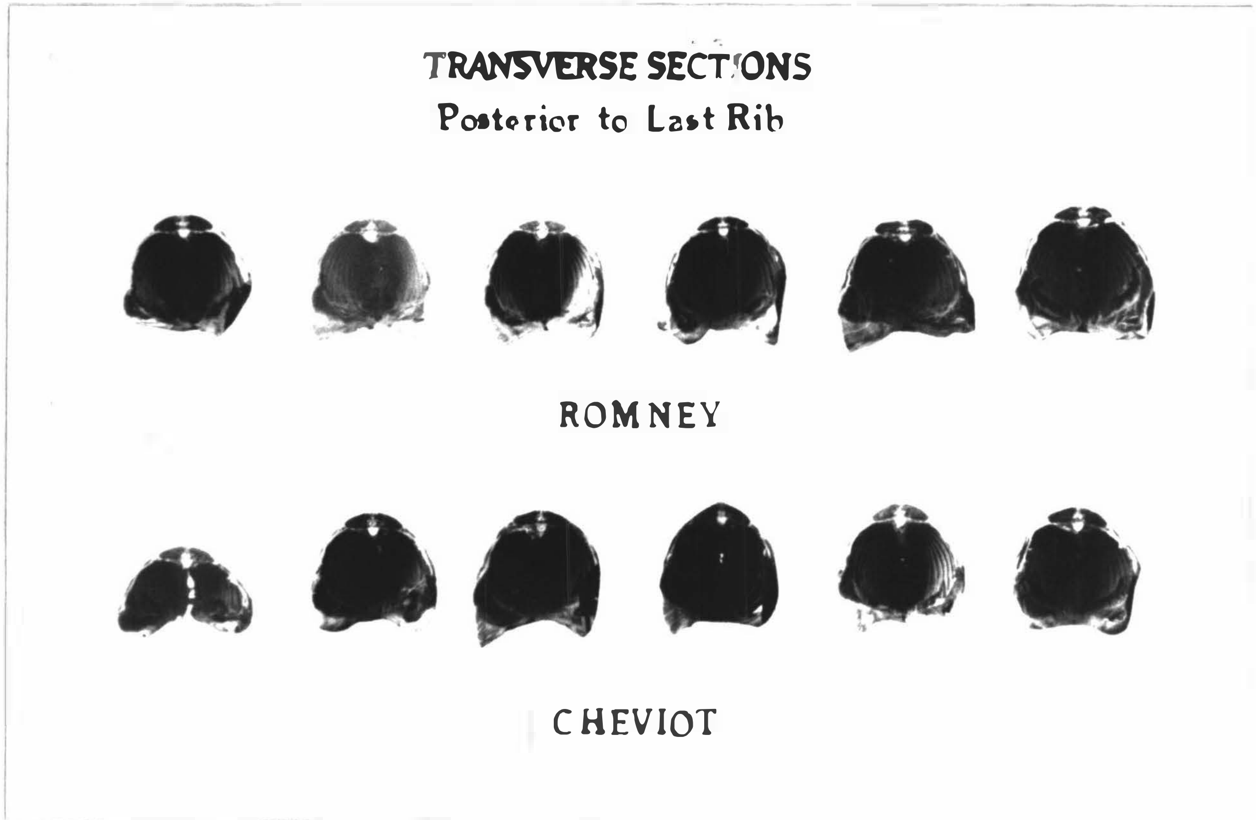


Fig. 20.--View of transverse section on the fore half of the carcasses. The cut was made between the thoracic and lumber vertebrae.

C. The Thoracic Vertebrae and Bones of the Thoracic Limb.

The current ideas regarding the causation of the particular shape of a bone are brought out by Murray (1936) who regards bone form as a compromise between a number of factors and forces. Briefly, these factors include:- (1) the influence of the form of the self-differentiating cartilage model of the bone in its embryonic period (largely controlled by hereditary factors); (2) the influence of stresses and strains as a result of use or functional activity; (3) the pressure of muscles, tendons and neighbouring organs; (4) the influence of an earlier form on its later variant in that the later shape has to be built on the existing foundation regardless of new functions; (5) the little understood necessity of the space which the organism needs for marrow and storage of fat; and (6) the possibility of certain growth patterns that have not changed to meet the need for a more efficient adaptation.

The influence of stress and strain has mislead a number of early workers by causing them to overemphasize its effects. It is certainly one of the predominant factors but not the complete story if the rest of the above factors are to be given their full due. This may be noted by observing bone differences in contrasted breeds of sheep reared in the same geographical environment (if other factors such as weight of animal, proportions, etc. are the same in both).

In making bone comparisons in this study the above was kept in mind. If, for example, differences in bone shape between the two breed types were found (other things being equal) then other reasons for the shape of a particular bone have to be added to that of the functional explanation.

In this study of the shoulder architecture of the sheep the bones considered include both the thoracic vertebrae and the main bones of the thoracic limb (the scapula, the humerus, the radius-ulna and the metacarpus). Since the thoracic vertebrae may contribute substantially to the high withers of the Cheviots, they were considered very closely.

1. __The thoracic vertebrae__

In all the animals dissected, there were thirteen thoracic vertebrae, although in sheep, occasionally there will be fourteen and, more rarely, twelve. The following measurements were taken on the thoracic vertebrae:- length, height of dorsal spines, angle formed by dorsal spines, transverse thickness of dorsal spines and width of dorsal spines.

Although the total length of the thirteen thoracic vertebrae was measured, the main effort was devoted to an observation of the spinous processes of each of these vertebrae. It was in this region where the greatest differences between shoulder types of the animals studied was in evidence. In analyzing the data obtained from the various measurements, the procedure as outlined by Snedecor (1946) for the comparison of two groups having equal numbers was used. As might be expected, there was no difference in the total length of the thoracic part of the vertebral column. This is shown in Table 37.

TABLE 37.

TOTAL LENGTH
OF THE THORACIC VERTEBRAE ("ThVA")

Group	d.f.	Mean (cm)	S.D.	S.E.	__t__
Romney	5	30.77	2.19	0.89	0.30 NS
Cheviot	5	30.50	0.45	0.18	

Although the means for the breed types are very similar (Table 37), the Romney group shows a wide variability as evidenced by a comparison of the standard deviations.

a) Height of the dorsal spines of the thoracic vertebrae ("ThVB")

These measurements were made with the view to obtaining the greatest vertical height of the bony portion of the spinous processes. The comparison between the breed types in these heights was made using the __t__ test. The means and analyses for the height of the thirteen dorsal spines appear in Table 38.

TABLE 38.

HEIGHTS OF
THE SPINOUS PROCESSES ("ThVB")

Vertebral number	Group	d.f.	Mean (MM)	S.D.	S.E.	t
T.1	Romney	5	43.67	2.58	1.05	5.03 **
	Cheviot	5	53.83	4.44	1.81	
T.2	Romney	5	48.50	3.02	1.23	5.26 **
	Cheviot	5	57.00	2.53	1.03	
T.3	Romney	5	48.67	2.34	0.96	7.61 **
	Cheviot	5	58.33	2.07	0.84	
T.4	Romney	5	48.00	2.90	1.18	7.25 **
	Cheviot	5	57.50	1.38	0.56	
T.5	Romney	5	46.67	3.07	1.25	4.29 **
	Cheviot	5	53.00	1.84	0.75	
T.6	Romney	5	43.33	2.58	1.05	4.53 **
	Cheviot	5	49.33	1.97	0.80	
T.7	Romney	5	42.33	3.07	1.25	3.16 *
	Cheviot	5	47.00	1.89	0.76	
T.8	Romney	5	41.50	2.74	1.12	1.87 NS
	Cheviot	5	44.00	1.78	0.73	<0.1
T.9	Romney	5	39.33	2.88	1.18	1.33 NS
	Cheviot	5	40.33	1.51	0.62	<0.3
T.10	Romney	5	35.00	3.27	0.93	0.74 NS
	Cheviot	5	34.50	2.34	0.96	<0.5
T.11	Romney	5	30.83	1.33	0.54	0.76 NS
	Cheviot	5	28.67	1.75	0.71	<0.5
T.12	Romney	5	23.67	1.63	0.67	1.35 NS
	Cheviot	5	24.83	1.33	0.54	<0.3
T.13	Romney	5	21.83	0.98	0.40	3.52 **
	Cheviot	5	23.67	0.82	0.33	

Table 38 shows that the dorsal spines of the anterior end of the thoracic vertebrae are higher in the Cheviots than in the Romneys, the difference being greatest in the third and fourth spines. The differences in the breed means become less for each successive spine posteriorly, until, in fact, the means of the Romney become greater at the tenth and eleventh spines. The difference, is, however, reversed again on the twelfth and thirteenth spines, the thirteenth being significantly longer in the Cheviot. An attempt was made to illustrate this situation in Figure 21. This finding follows that of McKenzie and Marshall (1917) who classified the high withers of the Merino type and the wide, level shoulders of the Shropshire type in a group of Merino cross Shropshire sheep. They established the differences by palpation on the living animal. They found the spinous process of the fifth vertebra to be generally the highest, the tapering off in height beginning from there. Likewise, they found the second to the sixth dorsal spines to be the highest in all their animals.

In the present data the third thoracic vertebral spine was the highest in both breed types with practically no difference between the second and fourth within breed types. An interesting point to note is that the variance is greater in the Romney types throughout except for the first process and the eleventh process (this last one being where the mean of the Romney group is the larger). Also, the process with the widest standard deviation is the first in the Cheviots (4.44 mm) with all the rest in both breed types being 3.00 mm or less.

While a true type difference in the height of the dorsal spines has been established, it is difficult to give an adequate reason for this difference. In discussing the presence of high spinous processes over the anterior thorax, Howell (1944) states that such a condition is characteristic of mammals with extremely large heads or large antlers. He adds that, in wild animals, heavy forequarters and light hindquarters are correlated with high spines. This follows the reasoning of Thompson (1942) who compares the skeleton of a quadruped with the framework of a cantilever bridge with a cantilever at either end. The vertebral column represents the compression member, the spinous processes are the high struts, and the ties are represented by the muscles and ligaments. Using this approach, Howell (1944) states that high spinous processes certainly would indicate strength in movement, but adds that low ones do not necessarily mean that strength is lacking. Since the head of the Cheviot

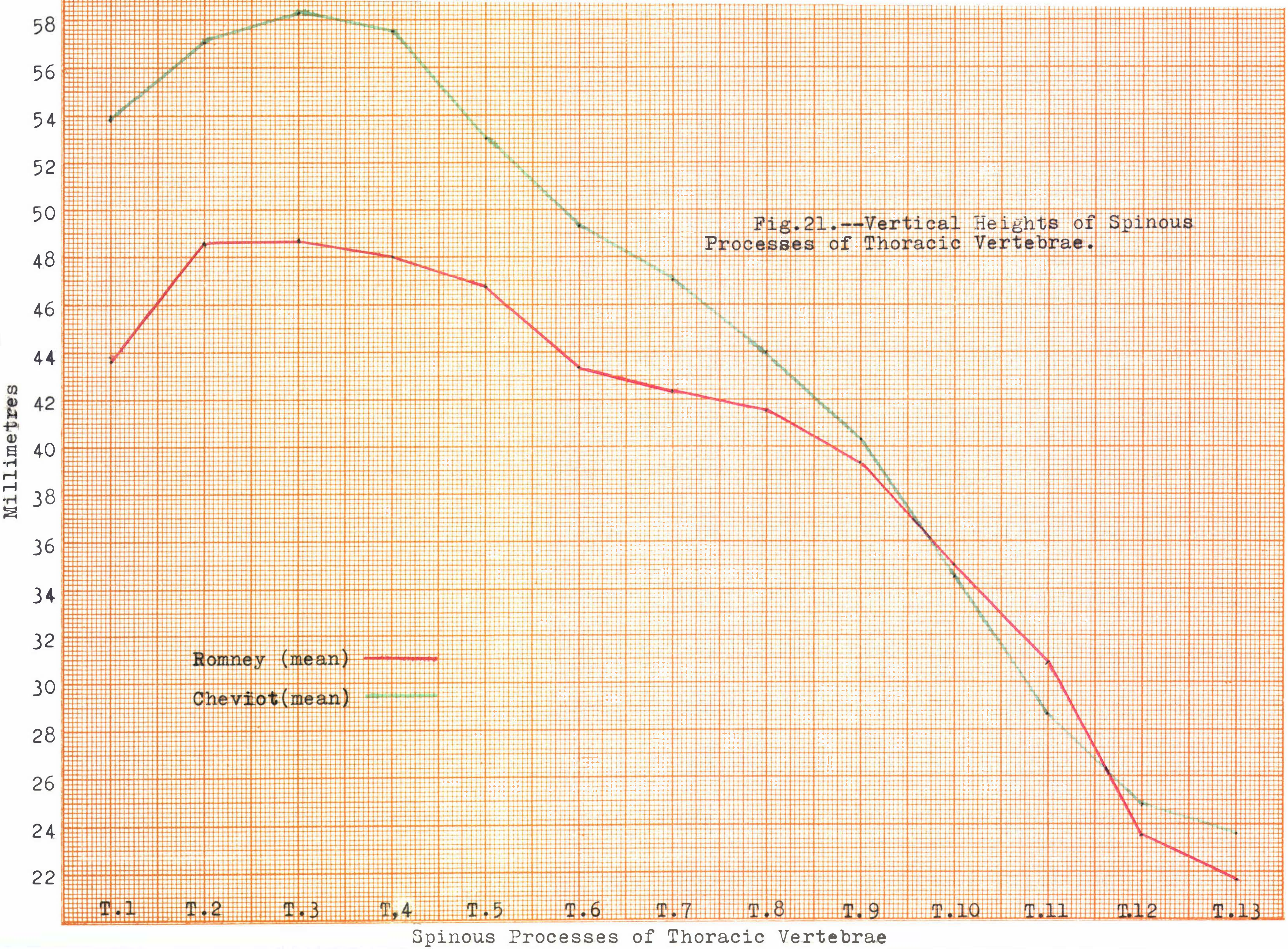


Fig.21.--Vertical Heights of Spinous Processes of Thoracic Vertebrae.

type is not extremely large, nor are the forequarters much larger in proportion to the hindquarters, nor does the breed have heavy horns, the reason for the higher spines must be found elsewhere. Certainly the relation between strength in movement and the height of the processes needs more investigation. It is possible, for instance that the higher struts give greater leverage to the ties (the ligamentum nuchea which supports the free end of the anterior cantilever).

b) Angles of the dorsal spines of the thoracic vertebrae ("ThVC")

This measurement, as described previously in Section II, is the angle between the line of the vertebral column and the dorsal spines of the thoracic vertebrae. The data analyzed for the angles appear in Table 39.

As may be readily discerned, these spinous angles were so extremely variable within breeds, that a breed type difference made itself apparent only in one instance. This was in the case of the twelfth vertebra where the Cheviot had a significantly greater angle. On a study of the means in Table 39, however, it is found that the Cheviot type has a slightly greater angle throughout. This would indicate a tendency for the first eleven spinous processes to be slightly more erect and the last two to slope a little more in the anterior direction. In both breeds the first spinous process has a rather large angle, but this gradually decreases with each successive spine (caudally) until the least angle is reached on the sixth vertebral spine. After the sixth vertebral spine the angle increases gradually at first and then more rapidly with each succeeding spine. However, it must be said that, although both breed types follow the same general pattern in the spinous angle, there is no significant difference between types. It is to be noted that the very lowest standard deviation is 3.27 degrees and more usually it is between four and seven degrees.

In order to obtain a comparison with the spinous angles as listed by Hammond (1932), the first six spinous angles were measured by the method he described. The mean angles were calculated for each breed type and the six added together for

TABLE 39

THE ANGLES
OF THE SPINOUS PROCESSES OF THE THORACIC VERTEBRAE ("ThVC")

Vertebral number	Group	d.f.	Mean (degrees)	S.D.	S.E.	t
T.1	Romney	5	58.50	5.92	2.42	1.18 NS
	Cheviot	5	63.00	7.24	2.96	<0.3
T.2	Romney	5	55.33	6.44	2.63	0.87 NS
	Cheviot	5	58.68	6.86	2.80	<0.5
T.3	Romney	5	52.17	4.96	2.02	1.17 NS
	Cheviot	5	55.33	4.41	1.81	<0.3
T.4	Romney	5	50.17	3.82	1.56	0.96 NS
	Cheviot	5	52.33	3.98	1.62	<0.4
T.5	Romney	5	48.17	3.71	1.51	0.38 NS
	Cheviot	5	49.00	3.89	1.59	
T.6	Romney	5	45.50	3.27	1.33	0.97 NS
	Cheviot	5	47.33	3.27	1.33	<0.4
T.7	Romney	5	47.50	3.94	1.61	0.81 NS
	Cheviot	5	48.50	3.73	1.52	<0.5
T.8	Romney	5	51.50	3.45	1.41	0.07 NS
	Cheviot	5	51.67	5.05	2.06	
T.9	Romney	5	56.67	5.75	2.35	0.14 NS
	Cheviot	5	57.00	5.06	2.07	
T.10	Romney	5	65.83	6.62	2.70	0.70 NS
	Cheviot	5	68.50	6.63	2.70	
T.11	Romney	5	79.17	5.00	2.04	1.18 NS
	Cheviot	5	83.33	7.06	2.88	<0.3
T.12	Romney	5	91.67	3.67	1.50	2.75 *
	Cheviot	5	97.83	4.07	1.66	
T.13	Romney	5	107.83	5.98	2.44	1.10 NS
	Cheviot	5	111.33	4.97	2.03	<0.3

the mean angle of all six spinous angles. The figures obtained were 52.3 degrees for the Cheviot types and 51.2 for the Romney types. These lie between Hammond's (1932) figures for improved mutton breeds and those of the semi-wild and less improved types.

The figures quoted by Hammond (1932) are as follows:-

Suffolk ram -- 59.6 degrees	Soay ram ---- 49.7 degrees
Suffolk ewes - 56.6 degrees	Shetland ram 49.0 degrees
Hampshire ram - 55.7 degrees	Merino ram -- 49.7 degrees

In suggesting a reason for the caudal slant of the anterior dorsal spines of the thoracic vertebrae, Howell(1944) says that spines sloping in one direction connote a stress from the opposite direction although a straight spine need not indicate a lack of stress or a different stress.

c) Transverse thickness of the dorsal spines ("ThVD")

The measurements were taken to the nearest 0.01 centimetre with the sliding calipers. The thickest portion was near the tip of the spinous processes in all the animals and, on a cursory inspection, it appeared that there was a breed type difference. The analyses presented in Table 70 shows this to be true.

It was found that the difference between the Romney and Cheviot types in this lateral thickness measurement existed mainly in the spines of the anterior thoracic vertebrae. The differences in thickness are greatest generally on the same vertebrae as those which have the greatest height difference. Throughout, the Romney types had the greater mean. The standard deviation, although it seems to fluctuate rather widely, is not consistently larger in one type or the other. In the Romneys there is a lack of height in these spines and they have significantly greater thicknesses in the second to fifth spinous processes. From this it would appear that bone growth is probably more equal for each breed type than it appears to be, but that this growth proceeds in different directions; that is, the Cheviots have longer but narrower spines while the Romneys have shorter and thicker spines. In this connection Hammond (1932) states that it appears that the extra growth made by the improved mutton breeds consists of a relatively greater thickening of the bone (dorsal spine) than of increase in its length growth. Hence, the Romney group could be regarded as a more improved mutton type than the Cheviot, if this aspect were the criteria.

TABLE 40.

TRANSVERSE THICKNESS
OF THE DORSAL PROCESSES OF THE THORACIC VERTEBRAE("ThVD")

Vertebral number	Group	d.f.	Mean (cm)	S.D.	S.E.	t
T.1	Romney	5	0.84	0.053	0.022	0.93 NS
	Cheviot	5	0.80	0.091	0.037	<0.4
T.2	Romney	5		0.130	0.053	2.37 *
	Cheviot	5	0.87	0.064	0.064	
T.3	Romney	5	0.90	0.106	0.043	2.77 *
	Cheviot	5	0.74	0.093	0.038	
T.4	Romney	5	0.82	0.079	0.032	3.75 **
	Cheviot	5	0.65	0.078	0.032	
T.5	Romney	5	0.77	0.095	0.039	2.54 *
	Cheviot	5	0.64	0.082	0.033	
T. 6	Romney	5	0.67	0.092	0.038	1.43 NS
	Cheviot	5	0.60	0.086	0.035	<0.2
T.7	Romney	5	0.58	0.083	0.034	1.53 NS
	Cheviot	5	0.52	0.049	0.020	<0.2
T.8	Romney	5	0.47	0.094	0.038	3.07 *
	Cheviot	5	0.43	0.040	0.016	
T.9	Romney	5	0.42	0.064	0.026	0.00 NS
	Cheviot	5	0.42	0.047	0.019	
T.10	Romney	5	0.43	0.041	0.017	0.00 NS
	Cheviot	5	0.43	0.042	0.017	
T.11	Romney	5	0.49	0.056	0.023	1.45 NS
	Cheviot	5	0.44	0.063	0.026	<0.2
T.12	Romney	5	0.54	0.060	0.024	1.11 NS
	Cheviot	5	0.50	0.065	0.027	<0.3
T.13	Romney	5	0.57	0.062	0.025	1.91 NS
	Cheviot	5	0.50	0.065	0.027	<0.1

It will be noted in Figures 22 to 27 that the lateral thickening does not occur noticeably for the entire vertical height of the spine but is more apparent in its dorsal half.

d) Posterior-anterior width of the dorsal spines ("ThVW")

This measurement is the distance from the posterior edge to the anterior edge of the spinous process at the mid-point in vertical height of each. Visual inspection gave the indication that there was a type difference and this is confirmed in the analyses that appear in Table 41.

In the comparison of the two groups, the t test shows a real difference in the first seven spines and in the twelfth spine. In all of these cases the Cheviot group is wider than the Romneys. After the fifth spine, in which the difference is greatest, the gap between the two means gradually narrows until, in fact, the mean shows the Romney group to be the widest at the tenth spine. However, from this point caudally, the Cheviot mean is the larger. The variance is not constant nor does it follow a pattern in either group, but it is higher in the Cheviot type in nine of the cases. No reference was found for a possible reason for this measurement being the larger, but it would follow for at least mechanical reasons that, if the lateral thickness remained the same, the width would have to be greater in order to maintain strength as the vertical height increases. Considering the function of these spines in the mammal as an attachment for the ligamentum nuchea, this could also partially be compensated for by a different angle. No angle difference could be ascertained although a difference in vertical height was apparent.

A photographic comparison of the thoracic vertebrae of the two breed types appears in Figure 28.

2. Bones of the pectoral limb

According to Hammond (1932), the relation of bone length to bone thickness differs between improved and unimproved types of sheep, the earlier maturing mutton types having bones thicker in relation to their length. This hypothesis was kept in mind in the following comparisons on the limb bones of the Cheviot and Romney types. In order to obtain figures to compare this relationship of bone thickness to bone length a number of measurements were necessitated. Wherever possible, sliding

TABLE 41.

POSTERIOR-ANTERIOR WIDTH
OF THE DORSAL PROCESSES OF THE THORACIC VERTEBRAE ("ThVE")

Vertebral number	Group	d.f.	Mean (cm)	S.D.	S.E.	t
T.1	Romney	5	1.36	0.127	0.052	4.76 **
	Cheviot	5	1.71	0.128	0.052	
T.2	Romney	5	1.35	0.043	0.018	4.53 **
	Cheviot	5	1.59	0.123	0.050	
T.3	Romney	5	1.36	0.096	0.039	4.17 **
	Cheviot	5	1.55	0.057	0.023	
T.4	Romney	5	1.35	0.079	0.032	3.57 **
	Cheviot	5	1.53	0.095	0.039	
T.5	Romney	5	1.32	0.048	0.020	5.93 **
	Cheviot	5	1.54	0.077	0.031	
T.6	Romney	5	1.29	0.068	0.028	3.71 **
	Cheviot	5	1.43	0.060	0.024	
T.7	Romney	5	1.29	0.071	0.029	2.55 *
	Cheviot	5	1.38	0.045	0.018	
T.8	Romney	5	1.29	0.042	0.017	1.35 NS <0.3
	Cheviot	5	1.36	0.120	0.049	
T.9	Romney	5	1.44	0.035	0.014	0.53 NS
	Cheviot	5	1.47	0.135	0.055	
T.10	Romney	5	1.44	0.122	0.049	1.44 NS <0.3
	Cheviot	5	1.35	0.150	0.061	
T.11	Romney	5	1.38	0.103	0.042	0.56 NS
	Cheviot	5	1.41	0.083	0.034	
T.12	Romney	5	1.65	0.073	0.030	3.83 **
	Cheviot	5	1.92	0.157	0.064	
T.13	Romney	5	2.14	0.107	0.044	1.89 NS <0.1
	Cheviot	5	2.27	0.131	0.053	

calipers with a vernier reading to 0.01 centimetres were used. This was possible for the measures of thicknesses and widths which are described in Section II. Also circumference measurements were made on the humeri and the metacarpi using a thin wire. This was done in order to correlate circumference with either the width or thickness. If either correlation were very high, then the caliper measurements, being a great deal more accurate,

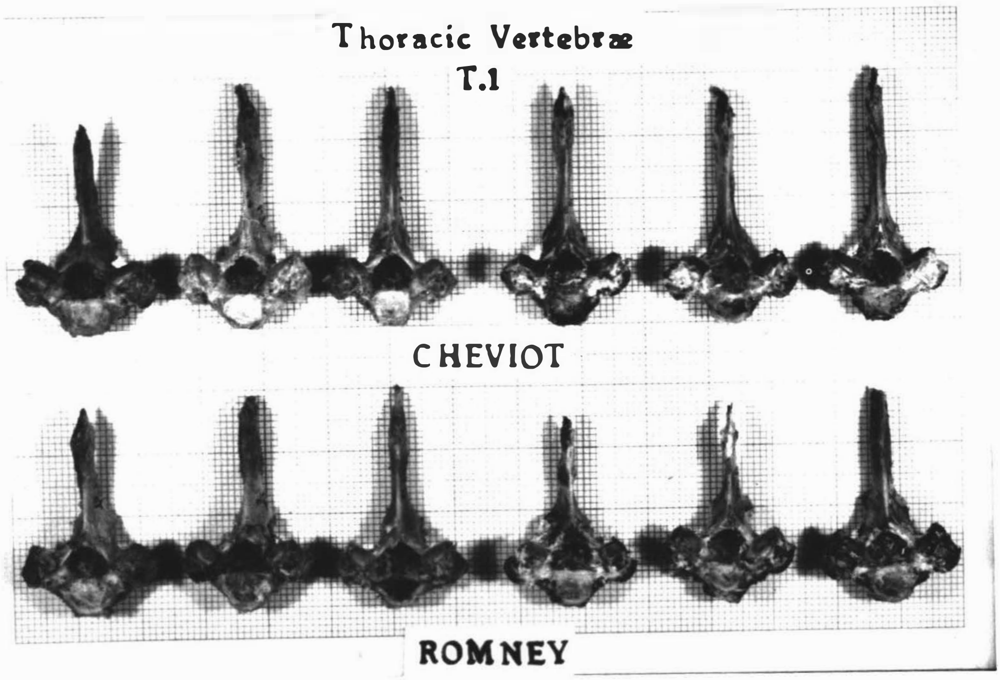


Fig. 22.--Frontal View of the First Thoracic Vertebra

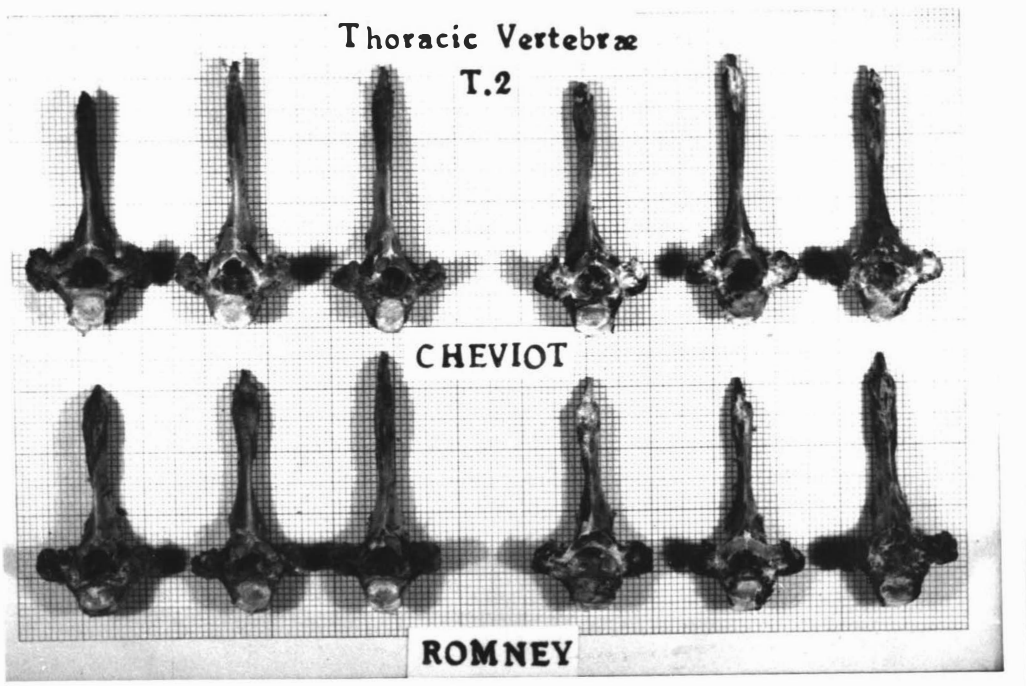


Fig. 23.--Frontal View of the Second Thoracic Vertebra

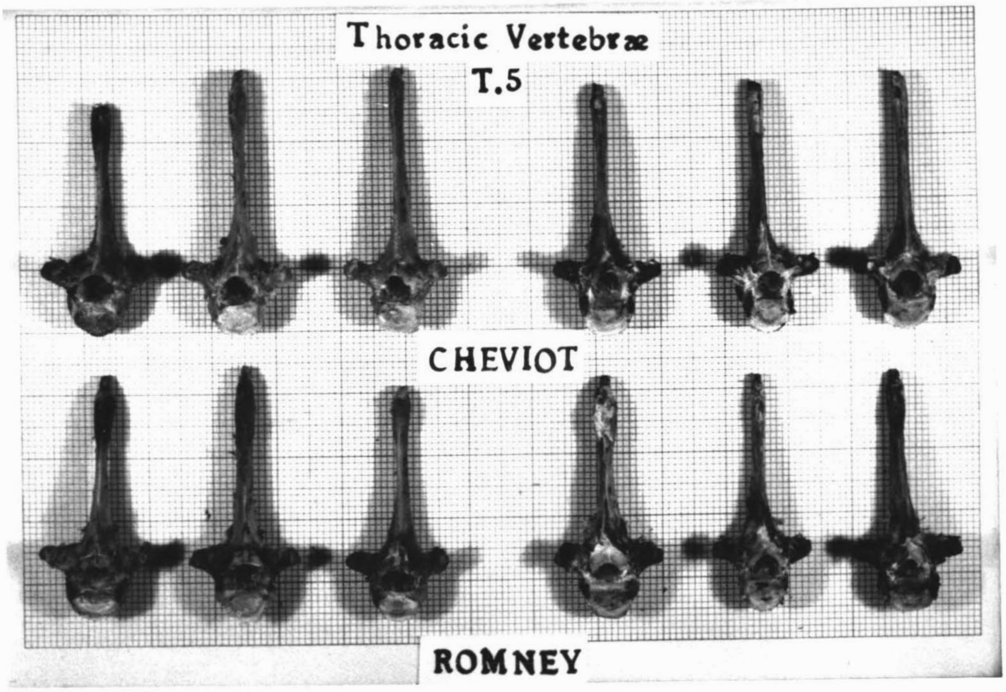


Fig. 26.—Frontal View of the Fifth Thoracic Vertebra

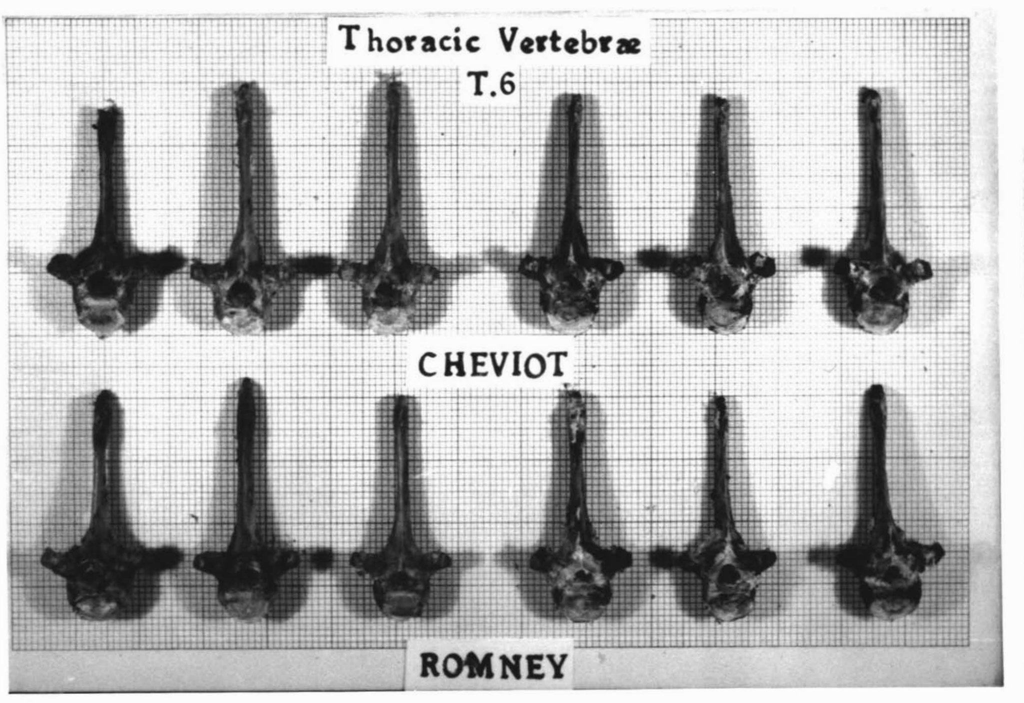


Fig. 27.—Frontal View of the Sixth Thoracic Vertebra

could be used in making the comparison between bone length and bone thickness.

The bones are examined in the order they appear on the limb of the living animal starting from the proximal end.

a) The scapula and its cartilage.

The scapula, in its uppermost position among the members of the fore limb chain, serves as the point of attachment for the muscles of the suprazonal group and part of the branchiomeric group whose function it is to attach the thoracic limb to the trunk. The scapula also acts as a base for the point of origin of the muscles of the shoulder joint. This bone and its cartilage were measured in a number of ways to determine if any differences existed between the breed types under consideration. The weight of the scapula, the weights of the cartilage of the scapula and the other measurements on the cartilage of the scapula were analyzed using the analysis of variance method. This was done in order to pick up any possible treatment effects on either the weights of these items or on the dimensions of the cartilage. The analyses of variance appear in Table 42.

The analyses of variance in Table 42 do not reveal any differences between breeds and inspection of Table 43 shows the breed means to be very much alike. The length of the cartilage of the scapula is, however, affected to a significant degree by the treatment. It is longer in the fixed group. There is no apparent explanation for this difference.

The rest of the analyses for the scapula is strictly a comparison between two groups of equal number and the t test as used previously was used. The measurements are as follows:- "ScA" (distal end to vertebral root of spine of scapula); "ScB" (anterior limit to posterior limit of vertebral border); "ScC" (vertebral root of spine to posterior limit of scapula); "ScD" (root of spine to anterior limit of vertebral border); "ScE" (middle of glenoid cavity to vertebral root of spine); "ScF" (middle of glenoid cavity to vertebral root of spine); "ScG" minimum width of neck of scapula). These are more fully described in Section II.

TABLE 42.

ANALYSES OF VARIANCE
FOR WEIGHTS OF THE SCAPULA AND ITS CARTILAGE AND
FOR MEASUREMENTS ON THE CARTILAGE OF THE SCAPULA.

Source	d.f.	SS	MS	F
For Weight of Scapula				
Total	11	831	-	
Between treatments	1	5	5	
Between breeds	1	40	40	
Interaction	1	49	49	
Error	8	737	92	
For Weight of the Cartilage of the Scapula				
Total	11	52.83	-	
Between treatments	1	6.23	6.23	1.11
Between breeds	1	0.51	0.51	
Interaction	1	1.20	1.20	
Error	8	44.88	5.61	
For Length of the Cartilage of the Scapula				
Total	11	7.05	-	
Between treatments	1	3.30	3.30	10.21 *
Between breeds	1	0.08	0.08	
Interaction	1	1.09	1.09	3.37
Error	8	2.58	0.323	
For Depth of the Cartilage of the Scapula (Ventro-dorsal)				
Total	11	1.00	-	
Between treatments	1	0.03	0.03	
Between breeds	1	0.03	0.03	
Interaction	1	0.00	0.00	
Error	8	0.94	0.12	
For Area of the Cartilage of the Scapula.				
Total	11	263	-	
Between treatments	1	52	52	2.00
Between breeds	1	2	2	
Interaction	1	1	1	
Error	8	208	26	

TABLE 43.

MEANS FOR WEIGHT
OF BONES AND CARTILAGE OF SCAPULA
AND FOR CARTILAGE MEASUREMENTS.

Item	Breed Type		Treatment		S.E.
	Romney	Cheviot	Fresh	Fixed	
Scapula (gm)	82.3	78.7	79.8	81.2	3.91
Humerus (gm)	110.0	104.3	105.5	108.8	5.22
Radius-ulna (gm)	81.5	78.3	81.3	78.5	4.16
Metacarpus (gm)	39.3 (3.14)*	37.9 (3.14)	38.3 (2.72)	39.2 (3.85)	
Cartilage of Scapula					
Weight (gm)	17.6	17.5	16.8	18.2	0.97
Length (cm)	15.4	15.1	14.7	15.8	0.23
Depth (cm)	5.5	5.4	5.4	5.5	0.14
Area (sq.cm)	75.7	76.5	74.0	78.2	2.08

*In this table the standard error was calculated from the error portion in the analysis of variance. Since there were a greater number of metacarpal bones in one of the treatments than in the other, one standard error will not do for all cases. For the metacarpal bones, the standard error for each group appears in brackets below each mean.

As may be seen from Table 44, the differences between breeds in the over-all dimensions of the scapula were small. It was found, however, that the ScC" measurement was larger in the Cheviot type than in the Romney indicating that the infra-spinous fossa was wider. This was not due to any difference in the total vertebral border width, but to a tendency for the proximal end of the spine of the scapula to be shifted in a posterior direction. This showed up to some extent in the "ScD" measurement but in this latter case the difference was not significant because of the small measurement and the relatively large standard deviation.

The scapular index as given by Sisson (1930) is the ratio between the greatest length and greatest breadth of the scapula. Sisson's average index for the horse is 1:0.5 and for the ox 1:0.6. No figures are given for the sheep. In this study the average scapular index for the Cheviot type was 1 : 0.81 and for the Romney type. 1 : 0.80. These indices indicate a broader appearance in the scapula of a sheep as compared with that of the horse or ox.

TABLE 44.

MEASUREMENTS OF THE SCAPULA.

Measurement	Group	d.f.	Mean (cm)	S.D.	S.E.	t
"ScA"	Romney	5	14.6	0.45	0.018	0.36 NS
	Cheviot	5	14.7	0.51	0.021	
"ScB"	Romney	5	11.7	0.53	0.022	0.78 NS <0.5
	Cheviot	5	11.9	0.33	0.014	
"ScC"	Romney	5	9.2	0.36	0.015	2.56 *
	Cheviot	5	9.7	0.37	0.015	
"ScD"	Romney	5	2.6	0.25	0.010	1.58 NS <0.2
	Cheviot	5	2.5	0.12	0.005	
"ScE"	Romney	5	13.7	0.65	0.026	0.89 NS <0.4
	Cheviot	5	13.9	0.42	0.017	
"ScF"	Romney	5	14.0	0.37	0.015	0.44 NS
	Cheviot	5	13.9	0.34	0.014	
"ScG"	Romney	5	2.35	0.173	0.008	0.49 NS
	Cheviot	5	2.31	0.102	0.004	

Most studies of scapular shape have been concerned with the vertebral border since it is this portion which seems to be the most variable. Gates (1946) concludes that scapular types in humans may be inherited and says that a change caused by functions from a concave type of vertebral border to a straight type of vertebral border has not been proved by observation. However, Wolffson (1950) in studies with growing rats was able to produce marked changes in the vertebral border, the scapular spine and the two lateral fossae by removing certain muscles in that region. He concluded that muscle function had considerable influence in shaping the final form of the vertebral border of the scapula. Howell (1944) says that the relative size of the lateral fossae of the scapulae of quadrupeds does not seem to depend on the requirements of the supraspinatus or the infra-spinatus muscles but upon the position of the spine of the scapula, and the over-all shape of the scapula is mainly governed by the requirements of the suprascapular musculature. He further adds that the size of these fossae is no indication of the muscular power involved as the muscles which have their origin in them do not necessarily always fit in them. Further-more, he was not able to correlate scapular proportions with cursorial specialization in any quadruped.

A photographic comparison of the scapulae of the two breed types studied appears in Figure 29.

b) The humerus.

In Table 45 the analysis of variance of the weight of humerus is presented.

TABLE 45

ANALYSIS OF VARIANCE
FOR THE WEIGHT OF THE HUMERUS.

Source	d.f.	SS	MS	F
Total	11	1478	-	
Between treatments	1	34	34	
Between breeds	1	97	97	
Interaction	1	27	27	
Error	8	1318	164	

Here again the treatment had no effect and the humeri of the breed types were very much alike. This is further sub-stantiated by inspecting the means in Table 43. As with the scapula, the rest of the measurements on the humerus were analyzed using the <u>t</u> test. The measurements, briefly, are:- "HA" (length of humerus); "HB" (circumference of humerus); "HC" (width at "HB"); and "HD" (depth at "HB").

The differences between the breed types in linear measurements were not significant (Table 46). However, the Romney group showed a slightly larger average in all cases.

Fig. 28.--Lateral View of the Thoracic Vertebrae

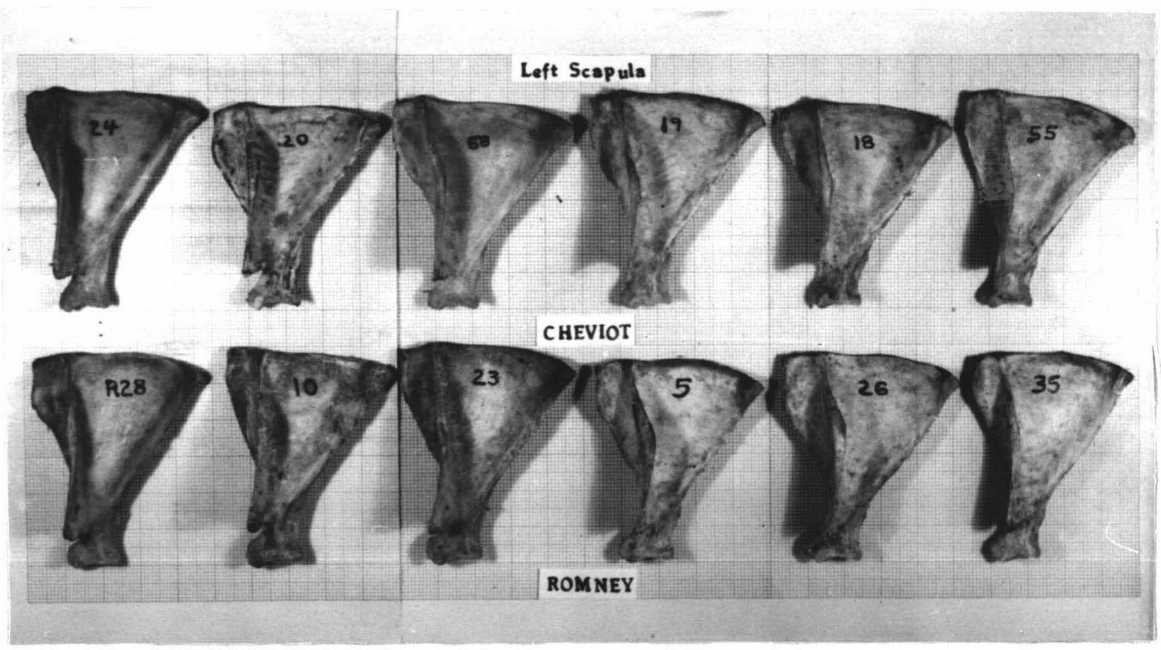


Fig. 29.--Lateral View of the Scapulae

Also, the standard deviation for the Romneys was larger in all measurements except depth.

Since the width and depth measurements could be taken with a relatively high degree of accuracy, while that of circumference was liable to error, the correlations between these variables were computed to see if either width or depth could be used to estimate circumference. These correlations are shown in Table 47.

TABLE 46

MEASUREMENTS ON THE HUMERUS.

Measurement	Group	d.f.	Mean (cm)	S.D.	S.E.	t
"HA"	Romney	5	14.3	0.45	0.19	1.03 NS <0.4
	Cheviot	5	14.1	0.14	0.06	
"HB"	Romney	5	7.5	0.33	0.11	2.20 NS <0.1
	Cheviot	5	7.1	0.30	0.12	
"HC"	Romney	5	2.10	0.157	0.064	1.76 NS <0.2
	Cheviot	5	1.95	0.137	0.056	
"HD"	Romney	5	2.23	0.138	0.056	0.37 NS
	Cheviot	5	2.18	0.297	0.121	

TABLE 47

CORRELATIONS OF MEASUREMENTS ON THE UMERUS.

Correlation	Pairs	r (Romney)	r (Cheviot)
Circumference ("HB") with Width ("HC")	6	+0.782 *	+0.981 **
Circumference ("HB") with Depth ("HD")	6	+0.777 *	+0.818 *

Correlation coefficient necessary for five per cent is 0.754 and for the one per cent level of probability it is 0.874.

It is evident that the width measurement gives a fairly good picture of cross-sectional size at the point where the circumference was taken. The circumference with width correlation is higher in both breed types than the circumference with depth correlation. For this reason, width instead of depth will be used later in calculating the thickness x length relation.

In order to illustrate correlations existing between the depth, width and circumference measurements these measurements were plotted on graph paper as shown in Figure 30 in the order of ascending circumference for each breed type. The lines for circumference and width follow each other very closely, but the line for depth seems to vary considerably. Since the measurement of width is much more accurate than the one of circumference, the former was used in graphing the length and width of the humeri as shown in Figure 31. Again the bones were placed in order of ascending width. Within each group some rather surprising results show up. In the Romney group, with increasing width and circumference, the length increases at first until it seemingly reaches a threshold at which point the length decreases with an increase in width.

Within the Cheviot group however, increasing width is associated at first with decreasing length. Then, for a period, the width and length relation is relatively constant and finally length begins to increase with greater width. It is realized that the numbers of animals involved in each case are too small to indicate any trends or differences, but certainly with such opposing changes, a more thorough investigation would be warranted.

The proportion of width to length is also plotted in Figure 31. It shows a different situation, however, as it points out that this proportion decreased with increasing width regardless of the direction of the length line. It does this at about the same rate and with about the same spread in each of the breed types under consideration.

In one other proportion, that of the width to the depth, there seemed to be a group difference. For the Romneys this proportion was 1 : 1.06 and for the Cheviots it was 1 : 1.12. Although this is but a small difference, it is mentioned because

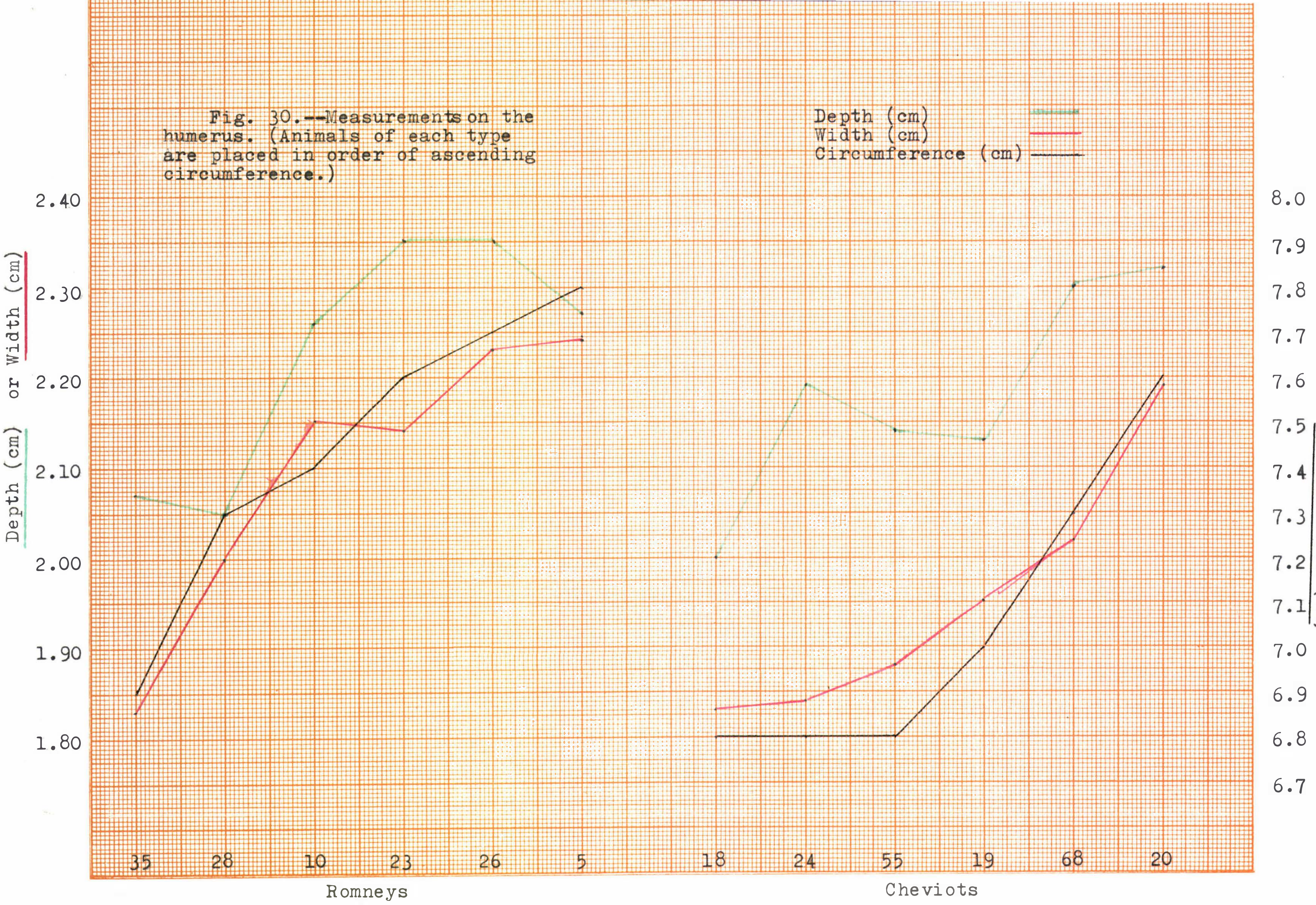


Fig. 30.--Measurements on the humerus. (Animals of each type are placed in order of ascending circumference.)

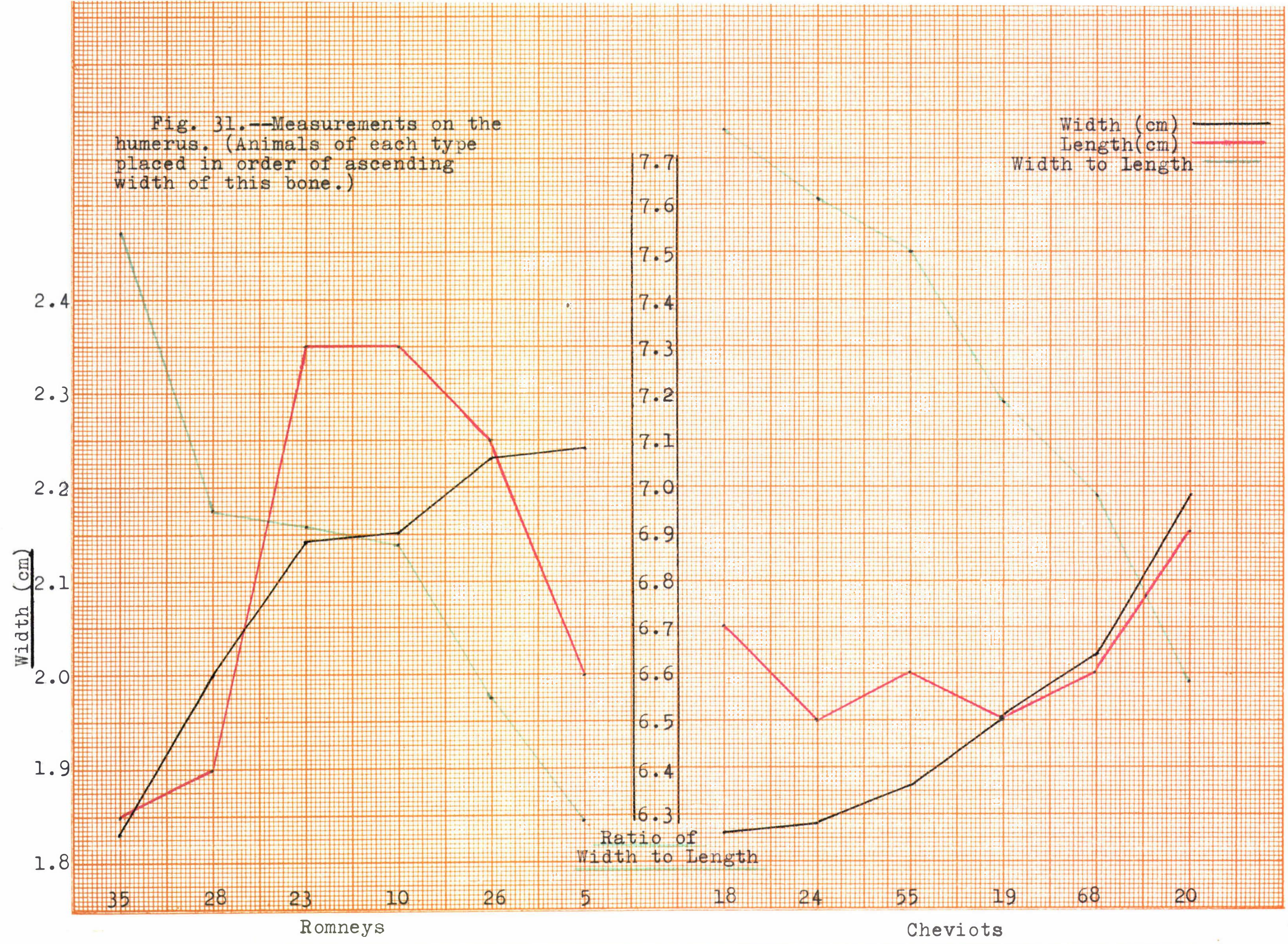


Fig. 31.--Measurements on the humerus. (Animals of each type placed in order of ascending width of this bone.)

as may be seen by consulting Appendix X, there is very little overlapping between groups. These ratios indicate a tendency for the humerus of the Romney at its mid-point to be nearly round while the same bone in the Cheviot group is more oval at the same point.

A photographic comparison of the humeri of both breed types appears in Figure 33.

c) The radius-ulna

The analysis of variance for the weight of the radius-ulna is presented in Table 48.

TABLE 48

ANALYSIS OF VARIANCE
FOR THE WEIGHT OF THE RADIUS-ULNA.

Source	d.f.	SS	MS	F
Total	11	942	-	
Between treatments	1	23	23	
Between breeds	1	29	29	
Interaction	1	53	53	
Error	8	837	104	

Again no breed or treatment difference is revealed in the weight of the radius-ulna. Also, the means as shown in Table 43 are very much alike.

The linear measurements taken on the radius-ulna are as follows:- "RA" (total length); "RB" (width at one-half of length); "RC" (depth at "RB"); and "RD" (minimum width below olecranon). The breed comparisons using the _t_ test are shown in Table 49.

In these analyses no real differences were apparent except in "RD" which is the minimum posterior-anterior width of the olecranon. This measurement was larger in the Romney group. Since the olecranon is the point of origin of the triceps brachii, a larger measurement here should indicate an origin of greater potential strength. Also the measurement should be correlated with the size of the triceps brachii muscle if the theory that bone form depends entirely on function holds true. That greater width does not necessarily mean a larger triceps muscle or vice versa is shown by the fact that the Cheviot group has the higher average weight of triceps brachii in the comparison of the two breed types.

TABLE 49.

MEASUREMENTS ON THE RADIUS-ULNA.

Measurement	Group	d.f.	Mean (cm)	S.D.	S.E.	t
"RA"	Romney	5	18.2	0.86	0.35	1.14 NS <0.3
	Cheviot	5	18.7	0.39	0.16	
"RB"	Romney	5	2.21	0.185	0.076	1.13 NS <0.3
	Cheviot	5	2.10	0.151	0.062	
"RC"	Romney	5	1.04	0.091	0.037	0.51 NS
	Cheviot	5	1.02	0.003	0.001	
"RD"	Romney	5	2.57	0.104	0.042	2.50 *
	Cheviot	5	2.43	0.089	0.036	

Because a true circumference could not be taken on the radius-ulna, this measurement was omitted for this bone. However, as with the humerus and metacarpus, both width and depth measurements were made at the mid-point in length.

The radii-ulnae were also graphed (Figure 32) in the order of their ascending width and related to depth and length. The proportion of width to length is also shown in the same Figure. The animals, with the exception of one in each group were ranked in the same order as was found in graphing the humeri in order of ascending width. As before, the depth of the radius-ulna at the mid-point of its length generally followed the curve for increasing width. However, with increase in width, the trend is toward an increase in length although the curve is very erratic. As with the humerus, the ratio of width to length drops with an increase in width. In Figure 32 it may be noticed that the curves for the Cheviot group are much more definite and not as variable as those for the Romneys. A general statement that, with an increase in length and width of the radius-ulna there is a narrowing of the ratio between these two items, might be made.

The average ratio of width to length is 1 : 8.30 for the Romney group and 1 : 8.94 for the Cheviot breed types. In this connection, Hammond (1932) states that the radius-ulna is proportionately slim in the semi-wild types of sheep and thick in the improved breeds. If this is so, then the Romney group tends to be the more improved mutton type.

Photographic comparisons of the radii-ulnae of both breed types appear in Figures 34 and 35.

d) The metacarpus.

The analysis of variance for the weight of the metacarpal bones is presented in Table 50.

TABLE 50.

ANALYSIS OF VARIANCE
FOR THE WEIGHTS OF THE METACARPUS.

Source	d.f.	SS	MS	F
Total	17	1175	-	
Between treatments	1	4	4	
Between breeds	1	8	8	
Interaction	1	0	0	
Error	14	1163	83	

Here again, the breed and treatment variance are negligible and Table 43 shows the means of the groups to be only a little more than one gram apart. Since nine metacarpal bones were available from each group, the analyses in Table 50 has the advantage of greater numbers.

The linear measurements taken on the metacarpal bones are as follows:- "MA" (total length); "MB" (circumference); "MC" (width); and "MD" (depth).

In every respect, except for length, the mean measurements of the Romney "cannon bones" were the larger. The last three measurements show the Romney group to be significantly larger in circumference, width and depth at the mid-point of total length. For length, there is a suggestion that the Cheviot is the longer, although the difference found is not

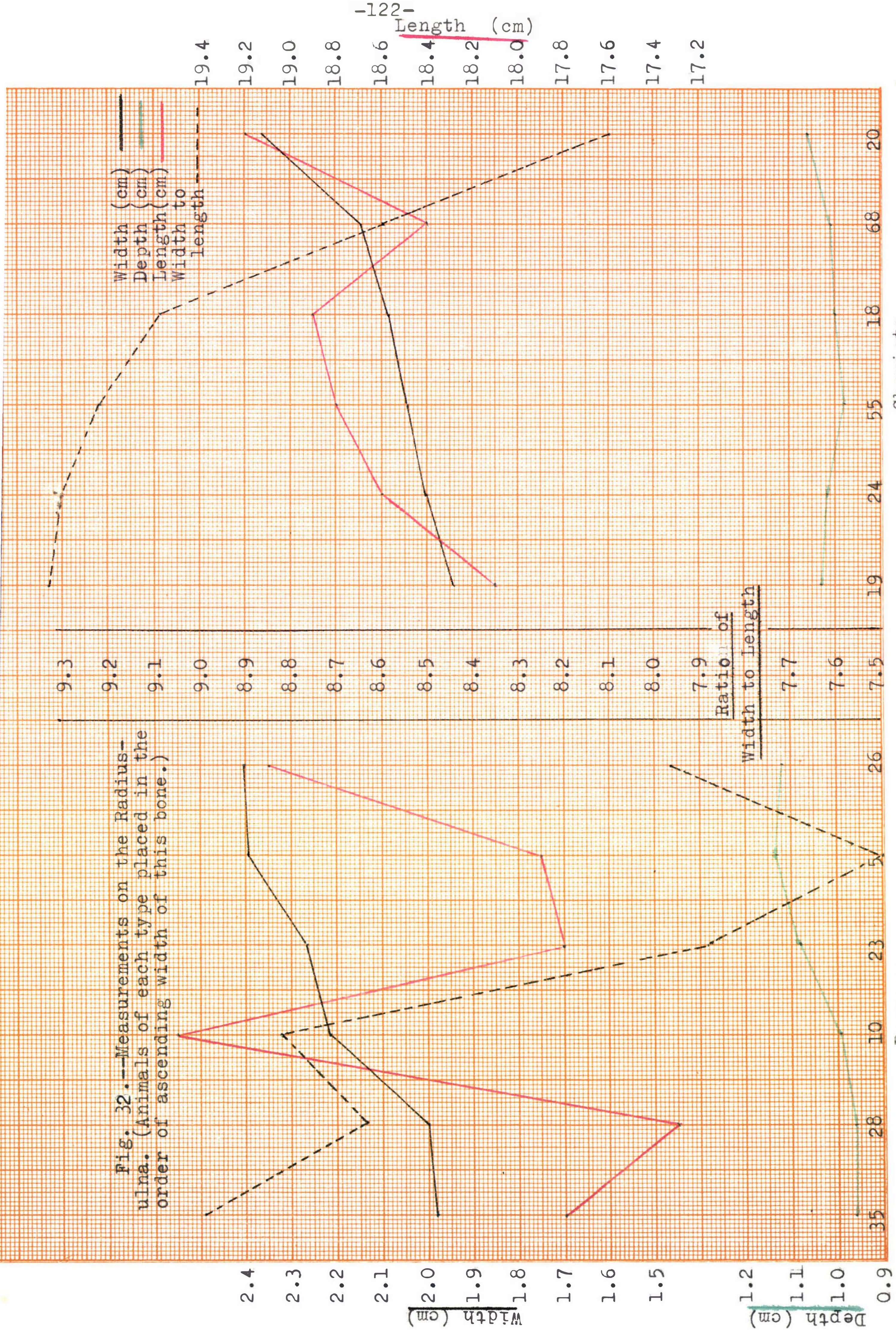


Fig. 32.--Measurements on the Radius-ulna. (Animals of each type placed in the order of ascending width of this bone.)

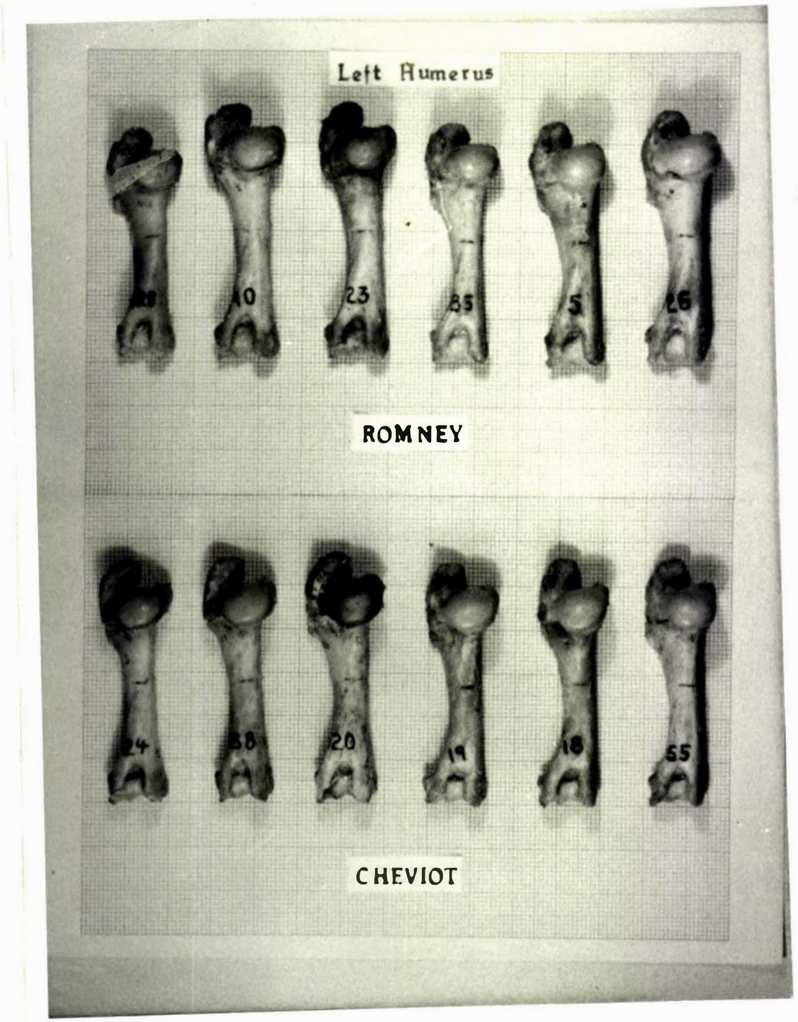


Fig. 33.--Posterior View of the Humeri

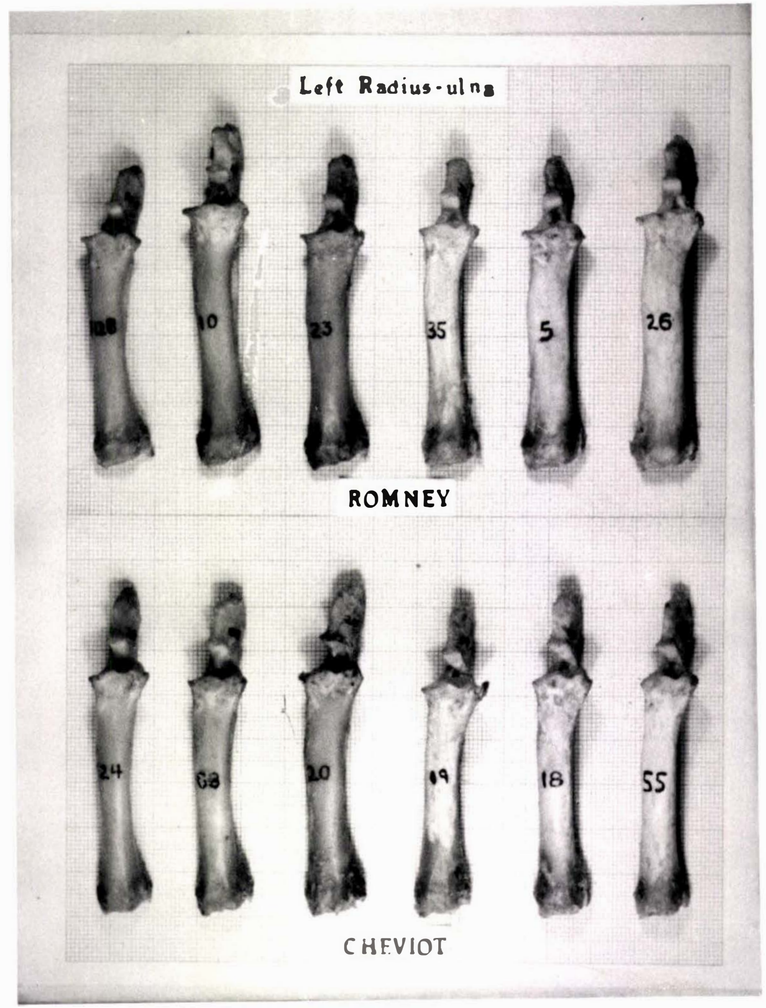


Fig. 34.--Anterior View of the Radii-ulnae

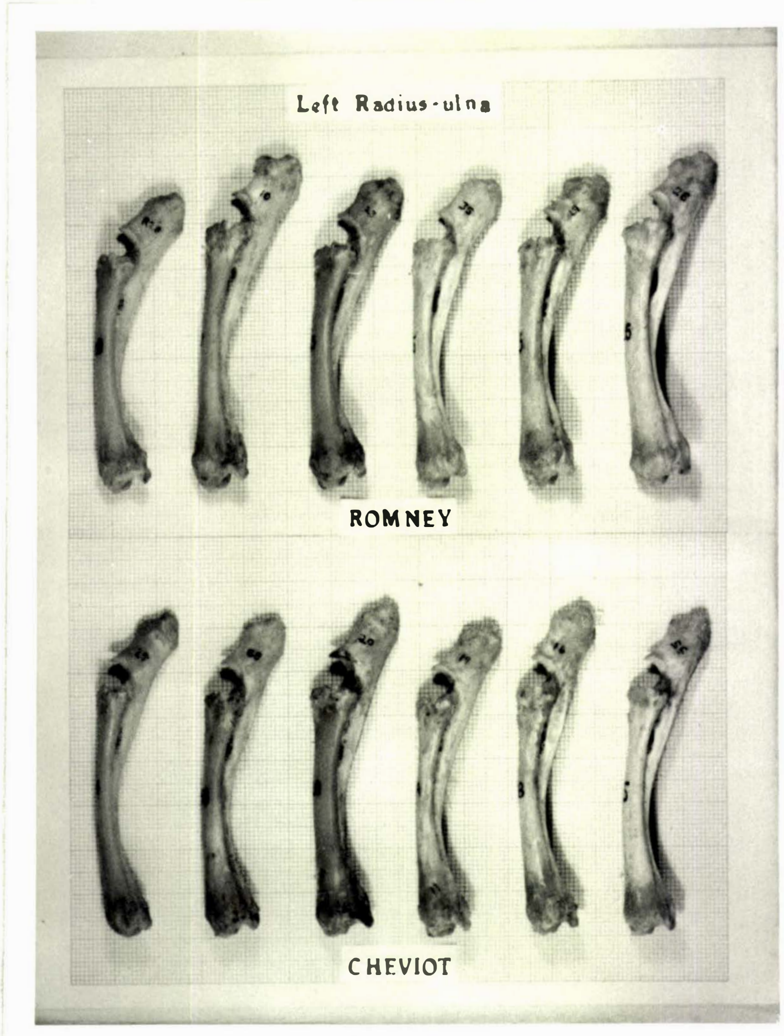


Fig. 35.--Lateral View of the Radii-ulnae

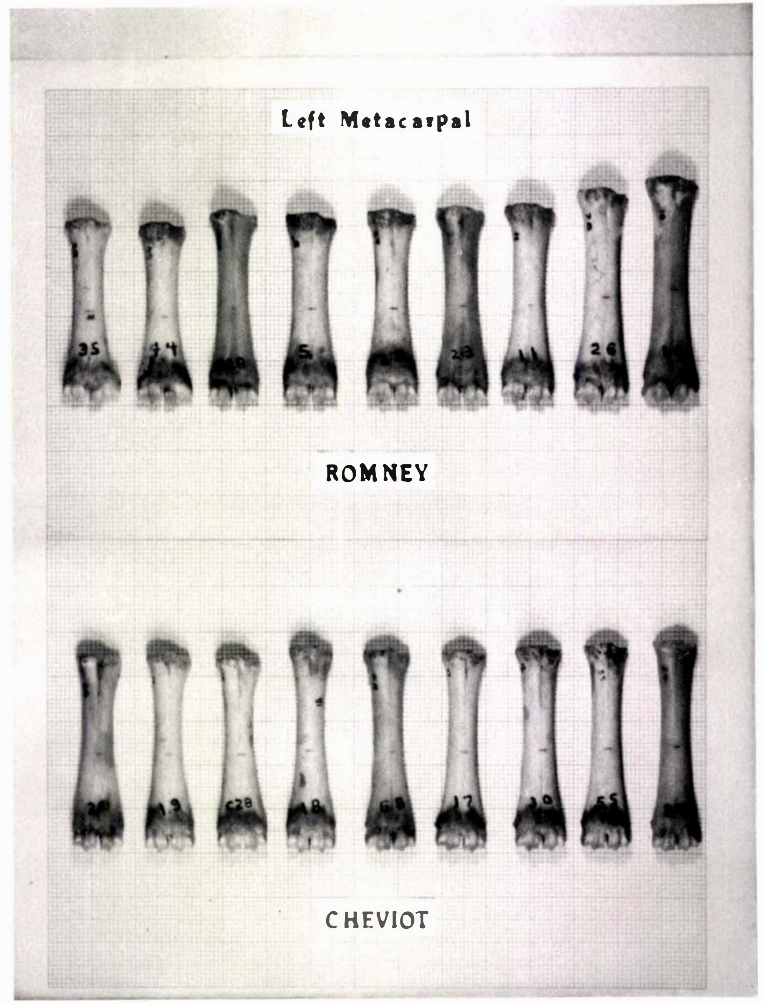


Fig. 36.--Anterior View of the Metacarpi

significant. The analyses in Table 51 indicate that, in appearance, the Cheviot group has "cannon bones" of longer and slimmer proportions while the Romney group has shorter, broader and more round metacarpals.

TABLE 51.

MEASUREMENTS ON THE METACARPUS.

Measurement	Group	d. f.	Mean (cm)	S. D.	S. E.	t
"MA"	Romney	8	11.2	0.80	0.27	1.74 NS
	Cheviot	8	11.7	0.29	0.10	<0.2
"MB"	Romney	8	5.4	0.26	0.09	3.95 **
	Cheviot	8	5.0	0.17	0.06	
"MC"	Romney	8	1.89	0.030	0.010	4.58 **
	Cheviot	8	1.70	0.026	0.009	
"MD"	Romney	8	1.22	0.051	0.017	21.00 **
	Cheviot	8	1.18	0.003	0.001	

As with the humerus, correlations were calculated to see whether either the width or depth of the metacarpus were more closely related to the circumference. These correlations are shown in Table 52.

TABLE 52.

CORRELATIONS OF MEASUREMENTS ON THE METACARPUS.

Correlation	Pairs	r (Romney)	r (Cheviot)
Circumference ("MB") with Width ("MC")	9	+0.893 **	+0.812 **
Circumference ("MB") with Depth ("MD")	9	+0.830 **	+0.545 NS

The correlation coefficient necessary for significance at the five per cent level is 0.666 and for the one per cent level, 0.765.

In both cases the circumference and width are very highly correlated, but only in the Romney group is the circumference and depth closely related. Hence, in the length-thickness comparisons, the width measurement will be used instead of circumference. This was done because the accuracy of circumference measurement was not high.

In Figure 37 the circumference, width and depth are plotted for each bone with each group arranged in order of increasing circumference. This was done in order to illustrate whether an increase in one of these measurements necessarily means a corresponding increase in one or both of the other measurements. As may be seen, it is apparent that an increase in circumference is accompanied by an increase in width and generally by an increase in depth. Although this last measurement does not seem to follow the others closely, it is a much better fit than was found with the humerus. Since the width measurement, using the sliding calipers, is much more accurate than the circumference measurement, using the wire, it was used as shown in Figure 38 to illustrate the relationship to the length of the bone.

In Figure 38 the bones are grouped in order of their increasing width. The relationship between width and length for the Romneys is very erratic but it seems that generally with an increase in width, there is an increase in length, but caution is necessary in the interpretation of this relationship in view of the variable nature of the curve. With the Cheviot group, however, there appears to be a definite and regular trend in the direction of a decrease in length with an increase in width. In both groups the ratio of width to length decreases with increasing width, although with much greater irregularity in the Romneys.

A comparison of the average ratio of width to length shows that the Romneys have a shorter "cannon bone" in proportion to its width. The figure for the Romneys is 1 : 5.92 and for the Cheviots it is 1 : 6.89. The average ratio of depth to width of the "cannon bone" at its mid-point in length is also interesting in that it demonstrates a tendency for the Cheviot

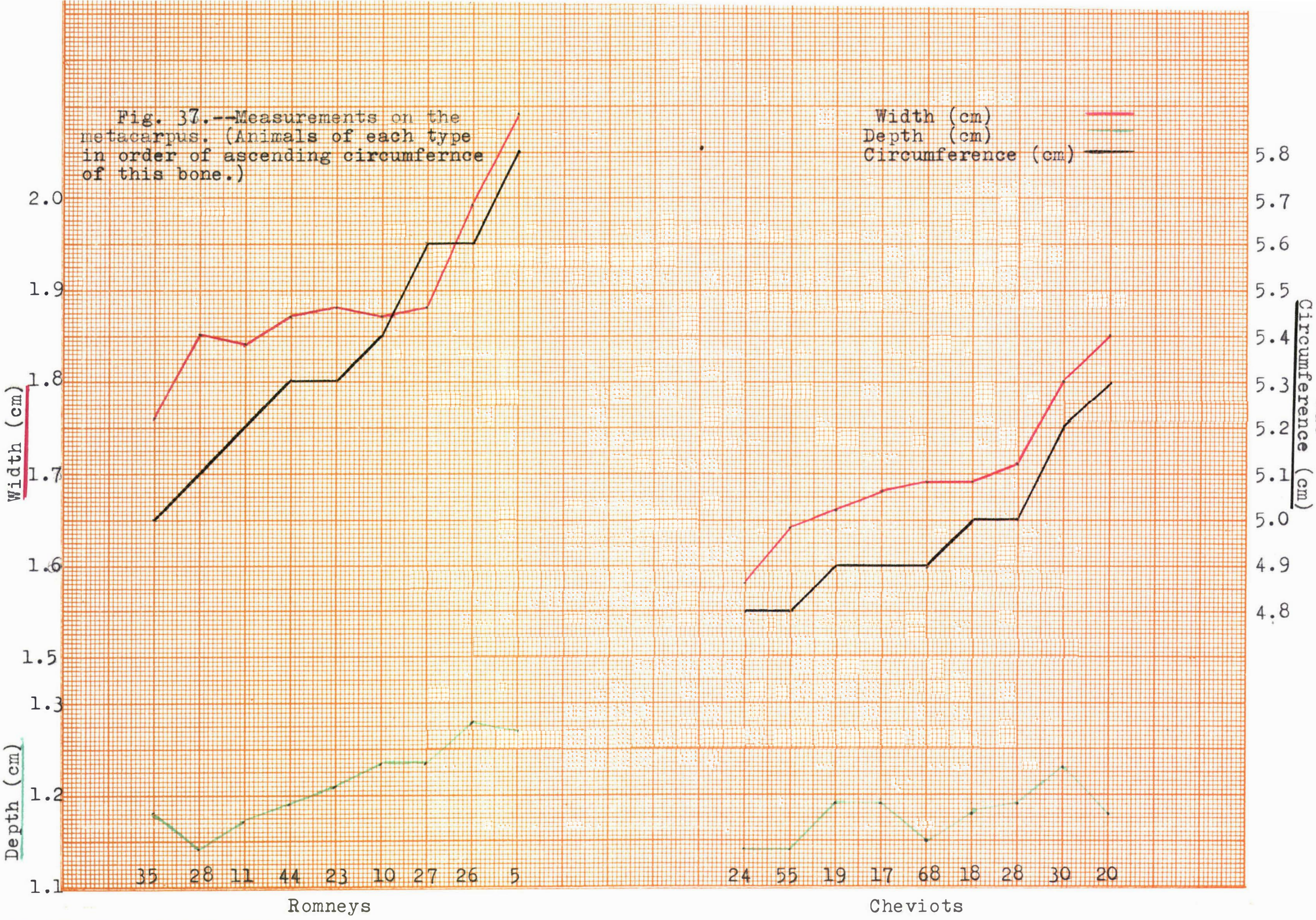


Fig. 37.--Measurements on the metacarpus. (Animals of each type in order of ascending circumfernce of this bone.)

type "cannon bone" to be more round at that point and for the Romney type to be more oval shaped. This average ratio is 1 : 1.55 for the Romneys and 1 : 1.44 for the Cheviots.

Concerning the breed differences in the "cannon bone" Hammond (1932) states that the reduction in size of this bone is one of the ways in which improvement of conformation is brought about, and that with the more improved mutton breeds, there is a shortening and a thickening of the metacarpus. In fact, he goes on to state that greater thickness of all bones in relation to their length is one of the chief differences between the bones of improved and the semi-wild types of sheep. Using a system of rectangular co-ordinates, Thompson (1942) illustrates that between different species of ungulates, the difference in "cannon bones" is merely a thickening in relation to length. If this be so, it should be feasible to identify differences within species.

A photographic comparison of the metacarpi of both breed types appears in Figure 36.

e) The relationship between weight and length of bone

The relationship between weight and length of bone does not necessarily remain the same from bone to bone. This results from the fact that there are differences in shape and differences in the proportion of compacta and spongy tissue in different bones of the body, the latter appearing to be related to the function of the bone concerned. A difference in water and fat content in different bones of the animal body is reported by Hofmeister (1873), and this would affect a length-weight comparison. In a comparison of the same bone from different animals, Hammond (1932) shows that there may be differences due to sex and suggests that since there are differences between wild and improved mutton breeds of sheep, there might also be breed differences within these types.

In order to ascertain whether a breed difference existed in the present study, the ratio of weight to length of each bone was calculated. Since the analysis of variance revealed no differences in weight due to treatment, the data were pooled and

Fig. 38.--Measurements on the metacarpus. (Animals of each type in order of ascending width of this bone.)

breed averages determined. The results are shown in Table 53.

TABLE 53

RATIO OF WEIGHT TO LENGTH
(Grams weight per centimetre length)

Group	Metacarpus	Humerus.	Scapula	Radius-ulna
Romney	3.52	7.66	7.00	4.46
Cheviot	3.25	7.39	6.60	4.19

Inspection of the mean ratios in Table 53 shows that the ratio of weight of bone to length is higher in the Romney group than in the Cheviots.

Although there are no significant differences between breeds, inspection of the data in Appendix XVIII shows that the ratio ranks each animal in a fairly constant position in all four bones examined. That is the animal having the highest ratio in one bone would have the highest in all bones and the animal with the lowest ratio of weight to length in one bone would accordingly have the least ratio in all bones.

D. The Ligamentum Nuchea.

The ligamentum nuchea is made up of two parts:- (1) the funicular part, and (2) the lamellar part. The funicular part consists of the main strands which arise on the occipital bone of the skull and lie along the back line until they merge into the lumbo-dorsal part of the supraspinous ligament. The lamellar part is that which forms a connection between the cervical vertebrae and the funicular part and the spines of the thoracic vertebrae.

In the sheep the funicular part is divided into two separate lateral strands which are merged antero-posteriorly at a point just anterior to the second thoracic dorsal spine where they make a definite split. One strand carries on posteriorly on each side of the dorsal region of the thoracic spines. After the division, the two strands are connected by a thin, membraneous tissue. In the thoracic region these strands are part of the origins of the trapezius and rhomboideus muscles. It was observed in the sheep dissected that after the division into two separate parts, the dorsal tips of the second to sixth thoracic spinous processes were the highest points in the thoracic region.

In this study only the funicular part was dissected out and measured. The measurements given for length and weight are not for the entire ligament of this part since it was severed between the thoracic and lumbar vertebrae when the carcasses were halved. Likewise, a short portion of the anterior end was not measured, since in both treatments the heads were removed before taking the above measurements. However, the points of section were constant for all sheep.

The length between the origin of the ligamentum nuchea and the point of severance described above was measured after exposing the ligamentum nuchea during dissection. A piece of soldering wire was fitted along its dorsal contour, marked and straightened. The marked distance was then measured to the nearest millimetre. The depth measurement was the ventro-dorsal distance at the point where the two strands divide while the width measurements were made just posterior to that division. The measurements were taken with a pair of dividers and read to the nearest millimetre. The means and analyses of variance for the measurements appear in Tables 54 and 55.

TABLE 54.

MEANS FOR
MEASUREMENTS ON THE LIGAMENTUM NUCHEA.

Measurement	Breed Type		Treatment		S.E.
	Romney	Cheviot	Fresh	Fixed	
Weight (gm)	31.2	30.4	28.5	33.0	1.37
Depth (cm)	0.72	0.72	0.63	0.80	0.06
Width of one strand (cm)	0.93	1.00	0.98	0.93	0.12
Width of whole (cm)	2.05	2.12	2.13	2.03	0.51
Length (before dissection)(cm)	44.4	43.9	44.6	43.7	0.51
Length (after dissection)(cm)	34.5	35.2	32.3	37.5	1.71

The means and the analyses of variance show that all measurements taken on the ligamentum nuchea were similar in both breed types. The treatment means also show little difference except for the measurements of weight and for length measured after dissection. In these it was found that weight after dissection was significantly greater for the fixed animals, and a tendency existed for the length after dissection to be greater in this group. Not much reliance should be placed on the difference obtained for the depth measurement as this measurement has a low mean length and is liable to error in measurement.

To get some idea about the elasticity of this ligament, a comparison was made between the length <u>in situ</u> and the length after dissection in each treatment group. The means and analyses of variance appear in Tables 56 and 57.

Table 56 shows that there is a very definite difference in length of the ligamentum nuchea before and after dissection which indicates that it is under considerable tension <u>in situ</u>. The means also indicate that the fixing of the animals resulted

TABLE 55

ANALYSES OF VARIANCE
FOR MEASUREMENTS ON THE LIGAMENTUM NUCHEA.

Source	d.f.	SS	MS	F
	For Weight			
Total	11	152.17	-	
Between treatments	1	59.86	59.86	5.32 *
Between breeds	1	2.08	2.08	
Interaction	1	0.16	0.16	
Error	8	90.07	11.26	
	For Depth			
Total	11	0.237	-	
Between treatments	1	0.084	0.084	4.42
Between breeds	1	0.000	0.000	
Interaction	1	0.000	0.000	
Error	8	0.153	0.019	
	For Width	(One strand)		
Total	11	0.087	-	
Between treatments	1	0.004	0.004	
Between breeds	1	0.014	0.014	
Interaction	1	0.002	0.002	
Error	8	0.670	0.084	
	For Width	(Both strands)		
Total	11	0.257	-	
Between treatments	1	0.030	0.030	1.20
Between breeds	1	0.014	0.014	
Interaction	1	0.013	0.013	
Error	8	0.200	0.025	
	For Length	(Before dissection)		
Total	11	16.45	-	
Between treatments	1	2.08	2.08	1.31
Between breeds	1	0.48	0.48	
Interaction	1	1.15	1.15	
Error	8	12.74	1.59	
	For Length	(After dissection)		
Total	11	241.15	-	
Between treatments	1	86.94	86.94	4.95
Between breeds	1	1.40	1.40	
Interaction	1	12.20	12.20	
Error	8	140.61	17.58	

TABLE 56

MEANS FOR THE LENGTH
OF THE LIGAMENTUM NUCHEA (CM).

Group	Breed Type		Condition		S.E.
	Romney	Cheviot	In situ	After Dissection	
Freshly slaughtered group	37.9	38.8	32.2	44.6	1.00
Fixed group	40.9	40.3	37.5	43.7	0.32

TABLE 57

ANALYSES OF VARIANCE
FOR LENGTHS OF THE LIGAMENTUM NUCHEA.

Source	d.f.	SS	MS	F
Freshly Slaughtered Group				
Total	11	522.2	-	
Between measurements (In and out of animal	1	461.2	461.2	76.23 **
Between breeds	1	2.1	2.1	
Interaction	1	10.5	10.5	1.74
Error	8	48.4	48.4	
Fixed Group				
Total	11	121.2	-	
Between measurements (In and out of animal	1	113.5	113.5	181.60 **
Between breeds	1	1.2	1.2	1.92
Interaction	1	1.5	1.5	2.40

in some loss in this tension as compared with the freshly slaughtered group. In the freshly slaughtered group the ligament contracted to seventy-two percent of its natural length, while in the fixed group it contracted to only ninety-three per cent of its *in situ* length.

Howell (1944) states that the ligamentum nuchea is better developed in artiodactyls than in perissodactyls and that the longer vertebral spines which are characteristic of the former appear to be correlated with this better development. He adds that the ligamentum nuchae is so arranged that its pull practically equalizes the weight of the head and neck.

While between species differences have been noted, it is unlikely that within species variation will be very apparent in the ligamentum nuchea.

E. The Musculature.

It was in the musculature that it was expected that the differences between the treatments would be the most noticeable. The formal saline solution used in the fixation went through all blood vessels and capillaries and thus made it more likely that these muscles would retain approximately the shape they held when this substance first entered. The muscles in the freshly slaughtered animals would possibly be distorted in three ways:- (1) the blood would run out allowing the blood vessels to collapse; (2) the muscle cells would lose the turgescence that they maintain in the living stage; and (3) the carcasses were hung on a gambrel overnight, thus forcing the less turgid muscles to react to gravity in a new direction for about a fifteen hour period. In other words, the form of the muscles and possibly even the weight could easily be different to that of the living, functioning muscle.

On the other hand, it was also quite possible that some changes in shape might occur in the muscles of the fixed animals. For example, when the animals were being fixed they were on their side and the normal body weight was not on the muscles that normally support this weight. Furthermore, it is possible that some swelling of the muscle took place through the entry of the formal saline solution into the muscle cells. Ostertag (1934) says that muscles, when still warm and not yet rigid, have a great capability of swelling (capacity for absorption of large quantities of fluid, such as saline solution, etc.).

The problem of a treatment effect on the weight of the individual muscles is easily solved by comparing the average weights and measurements, but the question as to which treatment most affects the weights and measurements is more difficult. Since this is a comparative study between two breed types, the actual living norm is not quite so important. However, it will have to be assumed that the formal saline fixed muscles more closely approach the normal than do the muscles from the freshly slaughtered animals.

In order to determine if there were any muscle variations due to the treatments administered just prior to dissection, an analysis of variance was applied to all muscle data comparisons. These comparisons include:- weight, length, width, depth and area. These are listed with each of the muscles studied and the muscles are grouped in the sections or divisions as described previously in Section II. Hence, in these muscles of the shoulder evey possible effort was made in order to determine if any difference existed between the Romney and Cheviot groups in the matter of muscle weight or muscle conformation.

Necessarily, for purposes of clarity, some of the information given in the introductory statement for each muscle analyses will be a repetition of that given in Section II.

1. The branchiomeric group

This group has three major divisions or muscles in the sheep. They are the trapezius, the brachiocephalicus and the omo-transversarius. The last two of these were treated as one muscle.

a) The trapezius.

This muscle, apart from its function as a trunk-limb connector, has the action of elevating the shoulder. Its origin, although varying as illustrated by Beaton and Barry (1942), is generally as follows:- the anterior part on the ligamentum nuchae and the posterior part on the supraspinous ligament from the dorsal spines of the thoracic vertebra. Its insertion is mainly along the spine of the scapula thus making it possible for it to move the scapula forward and upward as well as backward and upward. The means for the trapezius and the analyses of variance appear in Tables 58 and 59.

In the analyses of Table 59 the only real differences revealed were due to treatment. The muscles of the ordinary slaughtered group were significantly longer and were not as wide in the dorso-ventral measurement. As shown by the table of means (Table 58), the average area of the formal saline fixed

TABLE 58

MEANS FOR THE MUSCLE TRAPEZIUS

Measurement	Breed Types		Treatments		S.E.
	Romney	Cheviot	Fresh	Fixed	
Weight (gm)	57.2	63.3	58.2	62.3	4.70
Length (cm)	30.1	30.3	32.1	28.3	0.75
Width (cm)	12.4	13.6	10.7	15.3	0.69
Depth (cm)	0.65	0.65	0.65	0.65	0.05
Area (sq cm)	102.5	188.0	162.2	208.3	9.30

TABLE 59

ANALYSES OF VARIANCE
FOR THE MUSCLE TRAPEZIUS.

Source	d.f.	SS	MS	F
For Weight				
Total	11	1480	-	
Between Treatments	1	52	52	
Between breeds	1	114	114	
Interaction	1	234	234	1.73
Error	8	1080	135	
For Length				
Total	11	71.42	-	
Between treatments	1	41.81	41.81	12.19 **
Between breeds	1	0.06	0.06	
Interaction	1	2.08	2.08	
Error	8	27.47	3.43	
For Width				
Total	11	94.2	-	
Between treatments	1	65.8	65.8	23.17 **
Between breeds	1	4.2	4.2	1.48
Interaction	1	1.5	1.5	
Error	8	22.7	2.84	
For Depth				
Total	11	0.120	-	
Between treatments	1	0.000	0.000	
Between breeds	1	0.000	0.000	
Interaction	1	0.003	0.003	
Error	8	0.117	0.015	
For Area				
Total	11	11616	-	
Between treatments	1	6393	6393	12.34 **
Between breeds	1	90	90	
Interaction	1	991	991	
Error	8	4142	518	

group was significantly larger. Weight was not affected to any great amount by the treatment and neither was the depth of the muscle. The analyses in Table 59 indicate that the ordinary slaughter technique resulted in a shrinking and stretching effect. The stretching was naturally in the antero-posterior direction in accordance with the new position of the carcass as it hung on the gambrel.

The means show the Cheviot group as the larger inevery case except for depth of the muscle.

b) The brachiocephalicus and omo-transversarius muscles.

In this study these two muscles were dissected together and treated as one muscle as they are in very close association with one another. The dorsal border of the omo-transversarius lies next to the ventral border of the trapezius, and, in some cases, it was difficult to determine the division. It seemed, however, in the case of the animals carrying more fat that this division was more clearly evident, the muscles being up to 0.5 cm. apart. These two muscles originate on the wing of the atlas, the occipital bone of the skull, the ligamentum nuchea, the muscle rectus capitus ventralis major and a tendon from the mandible. The insertion of these muscles is:- for the omo-transversarius, the shoulder fascia and the tuber spinae, and for the brachio-cephalicus, the deltoid tuberosity of the humerus and the arm and shoulder fascia. Their action in locomotion is mainly that of helping to draw the limb forward. The means and analyses for these muscles appears in Tables 60 and 61.

TABLE 60

MEANS FOR
THE MUSCLES OMO-TRANSVERSARIUS AND BRACHIOCEPHALICUS

Measurement	Breed Types		Treatments		S.E.
	Romney	Cheviot	Fresh	Fixed	
Weight (gm)	113.3	109.8	101.2	122.0	4.80
Length (cm)	32.4	33.2	28.5	37.2	0.46
Width (cm)	8.5	7.8	7.5	8.7	0.29
Depth (cm)	1.08	1.20	1.18	1.10	0.04
Area (sq cm)	197.6	182.5	148.8	231.3	7.29

TABLE 61

ANALYSES OF VARIANCE FOR
THE MUSCLES OMO-TRANSVERSARIUS AND BRACHIOCEPHALICUS.

Source	d.f.	SS.	MS	F
	For Weight			
Total	11	2545	-	
Between treatments	1	1302	1302	9.43 *
Between breeds	1	37	37	
Interaction	1	102	102	
Error	8	1104	138	
	For Length			
Total	11	240	-	
Between treatments	1	225	225	180.0 ***
Between breeds	1	2	2	
Interaction	1	3	3	
Error	8	10	1.25	
	For Width			
Total	11	10.32	-	
Between treatments	1	4.81	4.81	9.54 *
Between breeds	1	1.47	1.47	2.92
Interaction	1	0.01	0.01	
Error	8	4.03	0.504	
	For Depth			
Total	11	0.129	-	
Between treatments	1	0.021	0.021	2.80
Between breeds	1	0.041	0.041	5.47 *
Interaction	1	0.007	0.007	
Error	8	0.060	0.0075	
	For Area			
Total	11	23775	-	
Between treatments	1	20418	20418	64.00 **
Between breeds	1	690	690	2.19
Interaction	1	115	115	
Error	8	2552	319	

The means in Table 60 show for these muscles that the Romney group is the heavier and wider. Also in the Romneys these muscles cover a greater area. The brachiocephalicus plus the transversarius from the Cheviots is longer and deeper. However, only in the case of depth is this difference significant.

The treatment means show a heavier, longer, wider and larger area covered in the case of the fixed animal while the freshly slaughtered group have a greater depth. These treatment differences are significant except for depth, the length and area difference being highly significant. The weight difference in analysing all the data for all muscles shows up very infrequently. The probable explanation for the treatment effect in this instance is that this muscle was exposed during the embalming process and remained partially exposed to the air until the time of dissection. This partial contact with the atmosphere over a period of time would certainly exert an influence on the weight of the muscle concerned.

In these muscles, the freshly slaughtered technique resulted in a shrinking effect, but it did not seem to be obvious in any one direction as in the case of the trapezius. These facts indicate that in the case of a large flat muscle as those of the branchiomeric group that the true shape and form was more closely retained through the use of formal saline injection and impregnation.

In comparing the tracings of the radiographs of the two carcasses X-rayed with those of the live animals (Figures 41 and 42), it will be noted that the limb bones are displaced forward in the carcasses. Since the above muscles are connected to the scapula and the humerus, an anterior movement of these bones would tend to shorten and thicken them. It must be pointed out that the above cannot be the entire explanation for the shape alteration, but feasibly could contribute a fair portion of the variance.

2. The dorsal division

This division contains three major groups of muscles. These are the suprazonal group, the shoulder derivatives and the elbow derivatives.

a) The suprazonal group

This group in the sheep includes two muscles:- the serratus ventralis and the rhomboideus. The serratus ventralis (sometimes called the serratus magnus) consists of two parts, the serratus cervicis and the serratus thoracis. Only the latter part was considered in this study.

1) The serratus thoracis

In the sheep dissected, the divisions of the serratus ventralis were not so clearly defined. The serratus thoracis, which forms much the greater part, was the portion of the muscle treated. It is a large, fan-shaped muscle with its ventral edge presenting a rather jagged appearance in its placing on the ribs. The surface that spreads over the ribs is the main origin of the larger, thoracic portion of this muscle. The muscle is inserted on the medial surface of the dorsal section of the scapula. This insertion extends to the adjacent portion of the cartilage of the scapula. Its chief action in locomotion is to elevate the thorax and to assist in the same motion as previously described for the trapezius.

The list of means (Table 62) shows the Romney group to have the larger average in all measurements except width (ventro-dorsal) and depth. This latter is a very small difference and is open to question as will be shown later. In length the Romney group is significantly longer while depth shows the Cheviots significantly deeper. This means that the Cheviot type on the average has a more circular shaped serratus thoracis while that of the Romneys tends more toward the elliptical form. The area and weight comparisons show no significant differences because of the wide variability present, mainly in the Romney group.

The treatment effects follow the same patterns as already established for the previous muscles described. The fixed muscles have the greatest weight, width and area, the latter two being significant. The weight difference is very small. The freshly slaughtered group has the highest average length and depth, but these differences are non-significant.

Interaction is present to a significant degree in the case of depth, indicating that, in this measure, the breed types did not react in a similar manner to the two treatments. With such a large muscle whose greatest depth occurs some distance in

TABLE 62

MEANS FOR
THE THORACIC PORTION OF THE SERRATUS MUSCLE

Measurement	Breed Type		Treatment		S.E.
	Romney	Cheviot	Fresh	Fixed	
Weight (gm)	294.6	280.0	279.3	295.1	15.84
Length (cm)	27.0	23.9	25.9	25.0	0.47
Width (cm)	19.6	20.9	18.8	21.7	0.40
Depth (cm)	2.00	2.00	2.12	1.97	0.09
Area (sq cm)	365.6	156.1	336.3	385.5	11.10

TABLE 63

ANALYSES OF VARIANCE FOR
THE THORACIC PORTION OF THE SERRATUS MUSCLE.

Source	d.f.	SS	MS	F
For Weight				
Total	11	13822	-	
Between treatments	1	752	752	
Between breeds	1	660	660	
Interaction	1	310	310	
Error	.8	12100	1513	
For Length				
Total	11	44.87	-	
Between treatments	1	3.32	3.32	2.52
Between breeds	1	27.61	27.61	20.92 **
Interaction	1	3.33	3.33	2.52
Error	8	10.61	1.32	
For Width				
Total	11	39.34	-	
Between treatments	1	23.93	23.93	25.19 **
Between breeds	1	5.77	5.77	6.07 *
Interaction	1	2.04	2.04	2.15
Error	8	7.60	0.95	
For Depth				
Total	11	0.689	-	
Between treatments	1	0.167	0.167	1.49
Between breeds	1	0.020	0.020	
Interaction	1	0.242	0.242	5.37 *
Error	8	0.360	0.045	
For Area				
Total	11	14963	-	
Between treatments	1	7252	7252	9.80 *
Between breeds	1	270	270	
Interaction	1	1519	1519	2.05
Error	8	5922	740	

from its edge, it is understandable that this measurement done with a pair of dividers would not be very reliable. This is especially true in the fresh dissected group where the data collected for depth shows a much greater range than in the fixed group.

Because of the firm and fixed origins of this muscle, the treatments would not affect the length, but the width measurement would be altered because of the twisting action exerted by the scapula and arm as they were rotated forward as a result of the carcasses being hung up overnight just prior to dissection. This may be seen by referring again to the tracings of radiographs that compare the live animal with the carcass. This action could also result in decreased area.

2) The rhomboideus

The rhomboideus, which serves as a lateral connector between the scapula and the trunk did not seem to be so clearly divisible into the cervical and thoracic parts in the sheep as is indicated by Sisson (1930) for the horse and the ox. Hence, the whole muscle was treated in one piece. This muscle has its origins in the same regions but underneath those of the trapezius muscle. The rhomboideus is inserted on the costal side of the cartilage of the scapula. This muscle supplements the action of the anterior part of the trapezius in drawing the scapula upward and forward.

TABLE 64

MEANS FOR THE RHOMBOIDEUS MUSCLE.

Measurement	Breed Type		Treatment		S.E.
	Romney	Cheviot	Fresh	Fixed	
Weight (gm)	56.5	52.2	51.8	54.8	2.35
Length (cm)	22.8	21.2	23.4	20.7	0.88
Width (cm)	9.0	9.4	9.5	8.9	0.08
Depth (cm)	1.08	1.17	1.15	1.10	0.07
Area (sq cm)	94.2	89.8	94.8	89.2	2.54

TABLE 65

ANALYSES OF VARIANCE
FOR THE RHOMBOIDEUS MUSCLE

Source	d.f.	SS	MS	F
For Weight				
Total	11	339	-	
Between treatments	1	3	3	
Between breeds	1	57	57	1.73
Interaction	1	5	5	
Error	8	264	33	
For Length				
Total	11	76.1	-	
Between treatments	1	23.0	23.0	4.99
Between breeds	1	8.7	8.7	1.89
Interaction	1	3.0	3.0	
Error	8	36.9	4.61	
For Width				
Total	11	6.91	-	
Between treatments	1	1.08	1.08	2.80
Between breeds	1	0.48	0.48	1.24
Interaction	1	1.26	1.26	3.26
Error	8	3.09	0.386	
For Depth				
Total	11	0.303	-	
Between treatments	1	0.008	0.008	
Between breeds	1	0.021	0.021	
Interaction	1	0.008	0.008	
Error	8	0.266	0.033	
For Area				
Total	11	47	-	
Between treatments	1	9	9	2.32
Between breeds	1	5	5	1.29
Interaction	1	2	2	
Error	8	31	3.9	

As seen from the means in Table 64, the Romney group has the highest average weight, length and area, and the Cheviot group has the greatest average width and depth in the rhomboideus muscle. In none of the cases is the difference large enough to even approach significance except in the case of width and there the difference is reduced by interaction.

Although there is no real treatment difference, there is a tendency for the muscle to be stretched in a lengthwise fashion in the same direction as in the trapezius of the freshly slaughtered group. The means also show a tendency for stretching to occur in the direction of increased width in the Romney group. This would be due again to the forward displacement of the pectoral limb as it hung on the gambrel. Since this muscle is, in shape rather like a hatchet, with its insertion being on the blade of the hatchet, this action can be visualized.

b) The shoulder derivatives of the dorsal division

In the sheep there are six muscles in this division and these can be further divided into the thoraco-dorsal matrix section and the axiliary matrix section.

1) The thoraco-dorsal matrix section.

This section is composed of two muscles, the latissimus dorsi and the teres major.

(a) The latissimus dorsi

Although this muscle is a trunk-limb connector, its main function is that of providing locomotive power rather than as a support muscle as has been the function of most of the preceding muscles. It is a relatively large, flat, fan-shaped muscle that has a broad origin in the lumbo-dorsal fascia. Its general pattern of muscle fibres is roughly at right-angles to those of the serratus thoracis which borders it medially. Its tendon of origin in the sheep does not seem to extend as far forward over the thorax as Tschaggeny and Vermeulen (1922) illustrate for the ox. The ventral part of the origin blends with the fascia that lies over the oblique abdominis externus muscle. This muscle is inserted into tendons which connect with:- (1) the teres tubercle of the humerus (with the teres major); (2) with the aponeurosis on the medial side of the long head of the triceps brachii; and (3) with a tendon shared with the deep pectoral muscle. Its functions are to assist in lifting the humerus upward and to the rear. When the limb is held stationary this muscle helps in drawing the trunk forward. It is one of the main opposing muscles to the brachiocephalicus in limb action.

TABLE 66

MEANS FOR
THE LATISSIMUS DORSI MUSCLE

Measurement	Breed Type		Treatment		S.E.
	Romney	Cheviot	Fresh	Fixed	
Weight (gm)	98.7	108.5	101.8	105.3	5.02
Length (cm)	25.0	25.4	25.2	25.1	0.55
Width (cm)	16.5	16.4	15.4	17.5	0.34
Depth (cm)	1.18	1.27	1.15	1.30	0.09
Area (sq cm)	247.1	248.0	239.3	255.8	10.44

TABLE 67

ANALYSES OF VARIANCE
FOR THE LATISSIMUS DORSI MUSCLE

Source	d.f.	SS	MS	F
For Weight				
Total	11	1817	-	
Between treatments	1	37	37	
Between breeds	1	290	290	2.00
Interaction	1	331	331	2.28
Error	8	1159	145	
For Length				
Total	11	20.57	-	
Between treatments	1	0.01	0.01	
Between breeds	1	0.44	0.44	
Interaction	1	5.71	5.71	3.17
Error	8	14.40	1.80	
For Width				
Total	11	18.27	-	
Between treatments	1	12.61	12.61	18.68 **
Between breeds	1	0.02	0.02	
Interaction	1	0.24	0.24	
Error	8	5.40	0.675	
For Depth				
Total	11	1.275	-	
Between treatments	1	0.675	0.675	13.78 **
Between breeds	1	0.208	0.208	4.24
Interaction	1	0.001	0.001	
Error	8	0.393	0.049	
For Area				
Total	11	6680	-	
Between treatments	1	807	807	1.23
Between breeds	1	2	2	
Interaction	1	541	541	
Error	8	5230	654	

As shown by Table 66, the Cheviot group is the larger in every respect except in the case of width and in this case the means are practically the same. However, the only difference that approachs significance is the one of depth. The means show about a ten per cent difference in weight, but since the spread is so large within groups, and also since interaction is present, it is unlikely that the difference is significant. The area covered is about the same in both breed types;- hence, it appears that the greater weight of the Cheviot group is absorbed in greater average depth or thickness.

The averages for the fixed group are greater in all cases except length. For width and depth, the fixed group is larger to a highly significant degree. In area covered the means indicate a difference, but because of the wide variability in the freshly slaughtered group, the difference is not a real one. The differences found in the treatments indicate that some shrinking and flattening had taken place in the freshly slaughtered group. The fact that there was no shrinking in the length measurement could be due to the pressure exerted by the forward rotation of the limb as it hung on the gambrel.

b) The teres major.

As mentioned before, it is the common opinion among zoologists that this muscle evolved from the latissimus dorsi, and became a muscle of the shoulder joint. It lies partially in a groove medial and anterior to the anterior border of the latissimus dorsi. The origin of the teres major is just ventral to the posterior angle of the scapula and on the scapula, and it is inserted into the common tendon shared with the latissimus dorsi which connects with the humerus at the teres tubercle. Its action involves helping to close the scapulo-humeral angle. In addition, it is concerned with adduction of the arm or rotating it medially as can be visualized by noting its attachment on the medial side of the humerus.

The means in Table 68 show that the Cheviots have the highest average in every measurement on the teres major except that of length. In weight, width, depth and area of the muscle

TABLE 68

MEANS FOR
THE TERES MAJOR MUSCLE.

Measurement	Breed Type Romney	Cheviot	Treatment Fresh	Fixed	S.E.
Weight (gm)	30.1	37.4	32.2	35.3	1.73
Length (cm)	14.8	14.6	14.2	15.2	0.07
Width (cm)	3.4	4.1	3.7	3.6	0.12
Depth (cm)	1.40	1.72	1.53	1.58	0.06
Area (sq cm)	33.0	41.7	36.5	41.5	1.64

TABLE 69

ANALYSES OF VARIANCE
FOR THE TERES MAJOR MUSCLE.

Source	d.f.	SS	MS	F
For Weight				
Total	11	338.1	-	
Between treatments	1	28.2	28.2	1.57
Between breeds	1	156.9	156.9	8.72
Interaction	1	8.7	8.7	
Error	8	144.3	18.0	
For Length				
Total	11	6.04	-	
Between treatments	1	2.81	2.81	10.68 *
Between breeds	1	0.06	0.06	
Interaction	1	1.07	1.07	4.07
Error	8	2.10	0.263	
For Width				
Total	11	2.33	-	
Between treatments	1	0.07	0.07	
Between breeds	1	1.54	1.54	17.60 **
Interaction	1	0.02	0.02	
Error	8	0.70	0.088	
For Depth				
Total	11	0.469	-	
Between treatments	1	0.007	0.007	
Between breeds	1	0.300	0.300	15.79 **
Interaction	1	0.090	0.090	4.74
Error	8	0.153	0.019	
For Area				
Total	11	298.6	-	
Between treatments	1	75.5	75.5	4.69
Between breeds	1	86.9	86.9	5.40
Interaction	1	7.6	7.6	
Error	8	128.6	16.1	

the differences are significant. In appearance then, the teres major muscle of the Cheviot group is broader and deeper but of much the same length as the same muscle in the Romney group. The muscle, in any case, is a rather wide, flattish one, and in the Cheviot group this effect is exaggerated.

Considering the treatment effects, although the fixed group has the greater measurements throughout, very little difference shows up except in the length which is significantly longer. These figures indicate an over-all shrinking of the size of the muscle, the greatest effect being a reduction in length.

Interaction shows up to some degree in the length and depth measurements.

2) The axillary matrix section

In the sheep there are four muscles in this section:- the subscapularis, the teres minor, the acromio deltoid and the spino-deltoid.

(a) The subscapularis

This muscle, which occupies the subscapular fossa, branches into three fairly distinct heads at its dorsal end. Most of the fossa is occupied by its origin and these three heads fuse as the scapula narrows towards its distal end. The subscapularis inserts into a tendon which passes over the glenoid notch of the scapula and attaches to the posterior eminence of the medial tuberosity of the humerus. Its obvious action is to help in adduction of the humerus.

In the subscapularis, the means for each breed type (shown in Table 70) are practically identical except for the width measurement in which the average is slightly higher in the Cheviot group. This lack of difference is not surprising when one remembers that no differences were found in the measurements on the scapula.

The same holds with the treatment comparisons except for the one of area, in which the fixed group had a significantly larger average. The lack of difference in the linear measure-

TABLE 70

MEANS FOR
THE SUBSCAPULARIS MUSCLE.

Measurement	Breed Type		Treatment		S.E.
	Romney	Cheviot	Fresh	Fixed	
Weight (gm)	77.2	77.2	75.3	97.0	2.69
Length (cm)	17.7	17.6	17.7	17.7	0.25
Width (cm)	8.6	8.9	8.8	8.7	0.25
Depth (cm)	1.45	1.40	1.36	1.48	0.08
Area (sq cm)	97.8	100.2	95.2	102.8	2.23

TABLE 71

ANALYSES OF VARIANCE
FOR THE SUBSCAPULARIS MUSCLE.

Source	d.f.	SS	MS	F
For Weight				
Total	11	400	-	
Between treatments	1	41	41	
Between breeds	1	0	0	
Interaction	1	12	12	
Error	8	347	43.4	
For Length				
Total	11	3.21	-	
Between treatments	1	0.00	0.00	
Between breeds	1	0.04	0.04	
Interaction	1	0.14	0.14	
Error	8	3.07	0.383	
For Width				
Total	11	3.35	-	
Between treatments	1	0.03	0.03	
Between breeds	1	0.27	0.27	
Interaction	1	0.12	0.12	
Error	8	2.93	0.366	
For Depth				
Total	11	0.403	-	
Between treatments	1	0.041	0.041	
Between breeds	1	0.009	0.009	
Interaction	1	0.020	0.020	
Error	8	0.333	0.0417	
For Area				
Total	11	454	-	
Between treatments	1	176	176	5.89 *
Between breeds	1	16	16	
Interaction	1	23	23	
Error	8	239	29.9	

ments was due to the fact that at the points of measurement, the muscle was firmly attached to the bone. In other portions, notably toward the distal end where there was no direct bone attachment, there was a chance that the fresh muscles could shrink without affecting the maximum width and length measurements but would alter the area measurements.

(b) The teres minor

This is a rather small muscle that is medial to the distal portion of the infraspinatus and the deltoideus pars scapularus muscles. Its origin is partly on the distal and posterior part of the infraspinatus fossa of the scapula where it begins to round off and partly on the lower middle part of the posterior border of the scapula. Its insertion is on and near the proximal region of the deltoid tuberosity of the humerus. It has an opposing action to that of the subscapularis in that it helps in adducting the humerus. In addition it assists in closing the scapulo-humeral angle (flexing of the shoulder joint).

In the teres minor the Cheviot averages (as shown in Table 72) are larger throughout except for length where this measurement is practically the same for both groups. However, only the differences in depth and area are significant although width shows a tendency in this direction.

By comparing the treatment means, it will be noted that the fixed group is the larger in every case except for width, in which case the averages are identical. The measurements that are significantly larger in the fixed group are the length, depth and area readings. The fresh treatment evidently resulted in a shrinking, flattening action. A probable reason why the treatment did not affect the width is that this muscle at the point of greatest width has a relatively round cross-section. Interaction appears only in the area measurement to any great extent. This is feasible as the smaller, thicker muscles were the most difficult to handle in the tracing process.

TABLE 72

MEANS FOR
THE TERES MINOR MUSCLE

Measurement	Breed Type		Treatment		S.E.
	Romney	Cheviot	Fresh	Fixed	
Weight (gm)	11.6	12.6	11.8	12.4	1.90
Length (cm)	8.5	8.4	8.1	8.8	0.14
Width (cm)	2.7	3.0	2.8	2.8	0.10
Depth (cm)	1.38	1.58	1.27	1.70	0.44
Area (sq cm)	15.0	17.0	15.2	16.8	0.44

TABLE 73

ANALYSES OF VARIANCE
FOR THE TERES MINOR MUSCLE

Source	d.f.	SS	MS	F
For Weight				
Total	11	22.13	-	
Between treatments	1	0.97	0.97	
Between breeds	1	3.20	3.20	1.48
Interaction	1	0.65	0.65	
Error	8	17.31	2.16	
For Length				
Total	11	2.85	-	
Between treatments	1	1.62	1.62	14.73 **
Between breeds	1	0.09	0.09	
Interaction	1	0.26	0.26	2.36
Error	8	0.88	0.11	
For Wdith				
Total	11	0.697	-	
Between treatments	1	0.004	0.004	
Between breeds	1	0.214	0.214	3.57
Interaction	1	0.000	0.000	
Error	8	0.480	0.060	
For Depth				
Total	11	0.837	-	
Between treatments	1	0.563	0.563	32.17 **
Between breeds	1	0.120	0.120	5.85 *
Interaction	1	0.014	0.014	
Error	8	0.140	0.0175	
For Area				
Total	11	34.67	-	
Between treatments	1	7.20	7.20	6.32 *
Between breeds	1	12.60	12.60	11.05 *
Interaction	1	5.76	5.76	5.05
Error	8	9.11	1.14	

(c) The deltoids

In the sheep there are two easily distinguished deltoid muscles, the pars acromialis and the pars scapularis.

i) The deltoideus pars acromialis

This part has its origin on the acromion of the spine of the scapula and is inserted on the humerus at the deltoid tuberosity. In this position it can help abduct the arm and flex the shoulder joint. It is a small, rather flat muscle, and was the larger of the two deltoids in all animals.

Here, again, the Cheviot group shows the highest average in all of the measurements. The differences in weight, width and area are significant. (Table 74)

Treatment has a definite and significant effect in that the muscles in the fixed group are significantly longer and greater in area. Treatment effects are not apparent for weight, width and depth. Thus, as before, the muscle has a tendency to decrease in length in the freshly slaughtered animals while its attachments prevent any width shrinkage. This results in a lessening of the area which it covers.

ii) The deltoideus pars scapularis

This was the smaller member of the pair in all of the animals dissected. Its origin is on the posterior border of the scapula and the aponeurosis that covers the infraspinatus. It is inserted partly into the fascia that covers the lateral head of the triceps brachii. At its ventral end, it begins to fuse with the pars acromialis. Its action is to complement that of the pars acromialis. The means and analyses of variance for this muscle appear in Tables 76 and 77.

In this muscle the Cheviot group has the higher average in all measurements except that of width. In this latter measurement, the means are very close together. In no case is the difference significant. However, in weight, depth and area the mean squares lie between the ten and five per cent level of probability.

Although the freshly dissected group has a slightly higher average in weight, the means for length, width, depth and

TABLE 74

MEANS FOR
THE DELTOIDEUS PARS ACROMIALIS MUSCLE.

Measurement	Breed Type		Treatment		S.E.
	Romney	Cheviot	Fresh	Fixed	
Weight (gm)	14.1	18.4	16.2	16.4	0.84
Length (cm)	8.5	8.8	8.0	9.2	0.07
Width (cm)	3.6	4.0	3.9	3.8	0.08
Depth (cm)	0.87	1.18	1.05	1.00	0.17
Area (sq cm)	21.1	24.4	20.5	24.9	0.92

TABLE 75

ANALYSES OF VARIANCE
FOR THE DELTOIDEUS PARS ACROMIALIS MUSCLE

Source	d.f.	SS	MS	F
For Weight				
Total	11	93.97	-	
Between treatments	1	0.10	0.10	
Between breeds	1	56.80	56.80	13.46 **
Interaction	1	3.08	3.08	
Error	8	33.79	4.22	
For Length				
Total	11	7.32	-	
Between treatments	1	4.44	4.44	13.49 **
Between breeds	1	0.24	0.24	
Interaction	1	0.01	0.01	
Error	8	2.63	0.329	
For Width				
Total	11	1.23	-	
Between treatments	1	0.02	0.02	
Between breeds	1	0.60	0.60	16.00 **
Interaction	1	0.31	0.31	8.27 *
Error	8	0.30	0.038	
For Depth				
Total	11	4.825	-	
Between treatments	1	0.075	0.075	
Between breeds	1	3.008	3.008	18.01 **
Interaction	1	0.409	0.409	2.45
Error	8	1.333	0.167	
For Area				
Total	11	132.23	-	
Between treatments	1	56.68	56.68	11.27 **
Between breeds	1	32.34	32.34	6.43 *
Interaction	1	2.99	2.99	
Error	8	40.22	5.03	

TABLE 76

MEANS FOR
THE DELTOIDEUS PARS SCAPULARIS MUSCLE

Measurement	Breed Types		Treatment		S.E.
	Romney	Cheviot	Fresh	Fixed	
Weight (gm)	11.6	14.2	14.5	13.0	0.89
Length (cm)	7.6	7.8	7.0	8.4	0.09
Width (cm)	3.4	3.3	3.1	3.6	0.05
Depth (cm)	1.32	1.50	1.30	1.52	0.06
Area (sq cm)	15.9	17.8	15.5	18.1	0.70

ANALYSES OF VARIANCE
FOR THE DELTOIDEUS PARS SCAPULARIS MUSCLE

Source	d.f.	SS	MS	F
For Weight				
Total	11	63.30	-	
Between treatments	1	0.12	0.12	
Between breeds	1	20.28	20.28	4.28
Interaction	1	4.98	4.98	1.05
Error	8	37.92	4.74	
For Length				
Total	11	10.55	-	
Between treatments	1	5.74	5.74	13.11 **
Between breeds	1	0.14	0.14	
Interaction	1	1.17	1.17	2.67
Error	8	3.50	0.438	
For Width				
Total	11	0.209	-	
Between treatments	1	0.066	0.066	3.86
Between breeds	1	0.003	0.003	
Interaction	1	0.003	0.003	
Error	8	0.137	0.0171	
For Depth				
Total	11	0.429	-	
Between treatments	1	0.140	0.140	6.70 *
Between breeds	1	0.100	0.100	4.68
Interaction	1	0.022	0.022	
Error	8	0.167	0.0209	
For Area				
Total	11	57.54	-	
Between treatments	1	20.53	20.53	6.89 *
Between breeds	1	10.53	10.53	3.53
Interaction	1	2.82	2.82	
Error	8	23.86	2.98	

area are greater in the formal saline fixed group. These differences are significant in the area and depth readings and highly significant for length. This indicates again a shrinking and flattening action in the freshly dissected muscles.

The interaction effect is not important except in the case of weight where it approaches but does not reach significance.

c) The elbow derivative of the dorsal division.

There are three muscles in this group in the sheep of which the triceps brachii is the most important. The other two are the tensor fasciae antibrachii and the anconeus.

1) The tensor fasciae antibrachii

This is a long, thin muscle which follows the posterior border of the triceps brachii. In the sheep, its origin is on the long head of the triceps brachii and it is inserted into a short tendon which blends partially with that of the insertion of the triceps brachii on the olecranon. The action of the tensor fasciae antibrachii is to tense the fascia of the forearm and to help extend the elbow joint.

TABLE 78

MEANS FOR THE
TENSOR FASCIAE ANTIBRACHII MUSCLE.

Measurement	Breed Type		Treatment		S.E.
	Romney	Cheviot	Fresh	Fixed	
Weight (gm)	16.9	16.8	15.8	18.1	0.94
Length (cm)	14.7	14.5	14.2	15.1	0.52
Width (cm)	2.3	2.4	2.3	2.4	0.09
Depth (cm)	1.07	1.10	1.02	1.15	0.06
Area (sq cm)	26.1	28.9	27.2	27.8	1.22

With this muscle, the table of means (Table 78) shows the group averages to be practically the same in all cases. In the treatment averages, the fixed group has a higher mean in every measurement but none of these are significant. In addition, interaction appears throughout to have very little, if any, effect.

TABLE 79

ANALYSES OF VARIANCE
FOR THE TENSOR FASCIAE ANTIBRACHII MUSCLE

Source	d.f.	SS	MS	F
For Weight				
Total	11	61.37	-	
Between treatments	1	18.50	18.50	3.47
Between breeds	1	0.04	0.04	
Interaction	1	0.16	0.16	
Error	8	42.67	5.33	
For Length				
Total	11	15.97	-	
Between treatments8	1	2.33	2.33	1.44
Between breeds	1	0.12	0.12	
Interaction	1	0.51	0.51	
Error	8	12.97	1.62	
For Width				
Total	11	0.450	-	
Between treatments	1	0.066	0.066	1.45
Between breeds	1	0.008	0.008	
Interaction	1	0.001	0.001	
Error	8	0.373	0.047	
For Depth				
Total	11	0.237	-	
Between treatments	1	0.054	0.054	2.58
Between breeds	1	0.004	0.004	
Interaction	1	0.012	0.012	
Error	8	0.167	0.0209	
For Area				
Total	11	95.29	-	
Between treatments	1	1.26	1.26	
Between breeds	1	23.80	23.80	2.67
Interaction	1	0.01	0.01	
Error	8	71.22	8.90	

2) The anconeus

This is another very small muscle which lies along the posterior aspect of the humerus. It has its origin on the distal half of this surface and is inserted on the lateral side of the olecranon. Its function is that of assisting in the extension of the elbow joint.

Table 80 shows the Cheviot group to have the larger

TABLE 80

MEANS FOR THE ANCONEUS MUSCLE

Measurement	Breed types		Treatment		S.E.
	Romney	Cheviot	Fresh	Fixed	
Weight (gm)	9.8	13.3	11.1	12.0	0.78
Length (cm)	6.6	7.0	6.7	6.9	0.15
Width (cm)	2.4	2.6	2.5	2.5	0.07
Depth (cm)	1.87	2.08	1.75	2.20	0.10
Area (sq cm)	10.9	12.6	11.5	12.0	0.54

TABLE 81

ANALYSES OF VARIANCE FOR THE ANCONEUS MUSCLE.

Source	d.f.	SS	MS	F
For Weight				
Total	11	70.79	-	
Between treatments	1	0.69	0.69	
Between breeds	1	35.71	35.71	9.84 *
Interaction	1	5.35	5.35	1.47
Total	8	29.04	3.63	
For Length				
Total	11	2.45	-	
Between treatments	1	0.14	0.14	
Between breeds	1	0.61	0.61	3.37
Interaction	1	0.37	0.37	2.23
Error	8	1.33	0.166	
For Width				
Total	11	0.55	-	
Between treatments	1	0.02	0.02	
Between breeds	1	0.19	0.19	6.33 *
Interaction	1	0.10	0.10	3.33
Error	8	0.24	0.13	
For Depth				
Total	11	1.222	-	
Between treatments	1	0.607	0.607	10.69 *
Between breeds	1	0.140	0.140	2.46
Interaction	1	0.021	0.021	
Error	8	0.454	0.057	
For Area				
Total	11	25.09	-	
Between treatments	1	0.75	0.75	
Between breeds	1	8.01	8.01	4.55
Interaction	1	2.25	2.25	1.28
Error	8	14.08	1.76	

average in every item. Although only the weight and width are significantly greater, the other three items show a marked tendency toward a breed difference.

In the comparison of the treatment means the fixed group is equal to or larger than the freshly slaughtered group in every case. However, only the depth measurement is significant. Hence, the only real treatment effect is that of a flattening action in the freshly dissected muscles. Interaction shows up to a small extent in most of the measurements. This probably indicates that such measurements are not as accurate as might be desired on small muscles.

3) The triceps brachii

This muscle, as its name implies, has three main divisions. They are the long head, the lateral head and the medial head. As the triceps brachii is a very important muscle in locomotion, each of these heads were dissected out and measured separately.

(a) The long head

This is by far the largest of the three heads. In the sheep it is roughly three times larger than the lateral head which is the next in size. Its origin is the posterior border of the scapula (along roughly three-fourths of this border), and it is inserted on the dorsal regions of the olecranon of the ulna. It has a joint action in flexing the shoulder joint and in extending the elbow joint.

The means in Table 82 show the members of the Cheviot group to have the heavier, wider and deeper measurement for the long head of the triceps brachii. The Romneys, however, are slightly longer. The only breed comparison showing significance is the one of width although weight and depth have a tendency in that direction. It may be concluded, then, that the Cheviot type has a more concentrated mass of muscle (long head of the triceps brachii).

In the treatment means it will be noted that the average is generally higher in the fixed group. The one exception is the width difference. The difference in length is the only one which is significant.

TABLE 82

MEANS FOR
THE LONG HEAD OF THE TRICEPS BRACHII

Measurement	Breed Types		Treatment		S.E.
	Romney	Cheviot	Fresh	Fixed	
Weight (gm)	146.0	160.2	149.3	156.8	5.36
Length (cm)	14.9	13.9	13.8	15.1	0.23
Width (cm)	8.0	8.9	8.5	8.3	0.21
Depth (cm)	3.32	3.60	3.30	3.62	0.27
Area (sq cm)	78.7	82.3	79.2	81.8	6.80

TABLE 83

ANALYSES OF VARIANCE
FOR THE LONG HEAD OF THE TRICEPS BRACHII

Source	d.f.	SS	MS	F
For Weight				
Total	11	2169	-	
Between treatments	1	169	169	
Between breeds	1	602	602	3.50
Interaction	1	19	19	
Error	8	1379	712	
For Length				
Total	11	10.86	-	
Between treatments	1	5.07	5.07	15.89 **
Between breeds	1	3.21	3.21	1.01
Interaction	1	0.03	0.03	
Error	8	2.55	0.32	
For Width				
Total	11	4.73	-	
Between treatments	1	0.14	0.14	
Between breeds	1	2.52	2.52	9.73 *
Interaction	1	0.00	0.00	
Error	8	2.07	0.26	
For Depth				
Total	11	1.13	-	
Between treatments	1	0.30	0.30	4.14
Between breeds	1	0.24	0.24	3.13
Interaction	1	0.01	0.01	
Error	8	0.58	0.07	
For Area				
Total	11	229	-	
Between treatments	1	21	21	
Between breeds	1	40	40	1.44
Interaction	1	16	16	
Error	8	222	27.8	

(b) The lateral head

This head of the triceps brachii, as its name implies, lies on the lateral surface of the arm. It covers the ventral part of the long head. Its points of origin are from the deltoid tuberosity toward and including part of the neck of the scapula. This lateral head is inserted into a tendonous sheet that connects with the lateral side of the olecranon and also blends in with the tendon of the long head of the triceps. Its action complements that of the long head in extending the elbow joint. The means and analyses for the lateral head will be found in Tables 84 and 85

TABLE 84

MEANS FOR
THE LATERAL HEAD OF THE TRICEPS BRACHII

Measurement	Breed Type		Treatment		S.E.
	Romney	Cheviot	Fresh	Fixed	
Weight (gm)	47.7	55.3	49.3	53.9	1.82
Length (cm)	10.2	11.1	10.6	10.7	0.19
Width (cm)	5.0	5.0	4.8	5.2	0.21
Depth (cm)	2.43	2.60	2.32	2.72	0.07
Area (sq cm)	37.0	40.7	37.3	40.4	1.52

The data in Table 84 shows that there is definite breed effect in the weight and length of this head of the triceps brachii with a possibility that there is also a group difference in depth. The means show that the members of the Cheviot group had a heavier, longer and possibly a deeper lateral head.

Treatment does not have a definite effect except in width where the muscles of the fixed group are significantly wider and in depth where the muscles of the freshly dissected lot are more shallow.

(c) The medial head

The medial head of the triceps brachii lies on the posterior and medial edge of the humerus and in the sheep extends for the entire length of the shaft of the humerus. In fact, a portion of its origin is on the neck of the humerus just below

TABLE 85

ANALYSES OF VARIANCE
FOR THE LATERAL HEAD OF THE TRICEPS BRACHII

Source	d.f.	SS	MS	F
For Weight				
Total	11	397	-	
Between treatments	1	56	56	2.80
Between breeds	1	176	176	8.80 *
Interaction	1	4	4	
Error	8	161	20	
For Length				
Total	11	4.25	-	
Between treatments	1	0.09	0.09	
Between breeds	1	2.09	2.09	13.20 **
Interaction	1	0.32	0.32	
Error	8	1.75	0.22	
For Width				
Total	11	2.76	-	
Between treatments	1	0.61	0.61	2.26
Between breeds	1	0.01	0.01	
Interaction	1	0.01	0.01	
Error	8	2.14	0.27	
For Depth				
Total	11	0.777	-	
Between treatments	1	0.480	0.480	19.20 **
Between breeds	1	0.083	0.083	3.32
Interaction	1	0.014	0.014	
Error	8	0.200	0.025	
For Area				
Total	11	189.8	-	
Between treatments	1	29.1	29.1	2.09
Between breeds	1	40.6	40.6	2.92
Interaction	1	9.0	9.0	
Error	8	111.1	13.9	

TABLE 86

MEANS FOR
THE MEDIAL HEAD OF THE TRICEPS BRACHII.

Measurement	Breed Type		Treatment		S.E.
	Romney	Cheviot	Fresh	Fixed	
Weight (gm)	12.7	17.2	15.1	14.8	1.15
Length (cm)	8.8	9.6	9.2	9.2	0.37
Width (cm)	3.7	4.1	3.9	3.9	0.19
Depth (cm)	1.2	1.3	1.2	1.3	0.06
Area (sq cm)	22.1	26.7	23.6	25.2	1.25

TABLE 87

ANALYSES OF VARIANCE
FOR THE MEDIAL HEAD OF THE TRICEPS BRACHII

Source	d.f.	SS	MS	F
For Weight				
Total	11	128.69	-	
Between treatments	1	0.24	0.24	
Between breeds	1	60.30	60.30	7.55 *
Interaction	1	4.20	4.20	
Error	8	63.95	7.99	
For Length				
Total	11	8.40	-	
Between treatments	1	0.01	0.01	
Between breeds	1	1.84	1.84	2.27
Interaction	1	0.09	0.09	
Error	8	6.46	0.81	
For Width				
Total	11	2.47	-	
Between treatments	1	0.00	0.00	
Between breeds	1	0.61	0.61	2.77
Interaction	1	0.10	0.10	
Error	8	1.76	0.22	
For Depth				
Total	11	0.35	-	
Between treatments	1	0.03	0.03	
Between breeds	1	0.03	0.03	
Interaction	1	0.10	0.10	4.40
Error	8	0.19	0.023	
For Area				
Total	11	156.19	-	
Between treatments	1	7.68	7.68	
Between breeds	1	63.48	63.48	6.75 *
Interaction	1	10.08	10.08	
Error	8	74.95	9.37	

the posterior part of the articulating surface of the head. Part of its origin is by means of a tendonous sheet attached to the surface of the bone which it borders. It is inserted on the medial and anterior part of the summit of the olecranon, and its main action is to help extend the elbow joint.

In the medial head portion of the triceps brachii, the Cheviot group has the higher means throughout. However, only the weight and area differences are significant. The fact that length and width both tend toward a real difference causes the area difference to be significant even though length and width are non-significant.

Treatment seems to have no effect in any of the measurements as the means are all practically the same in both groups. Interaction shows up to some extent in the depth measurement. This, it will be remembered, has been the case with other small muscles.

2. <u>The ventral division</u>

In the sheep, this division has three sections:- the infrazonal group, the shoulder derivatives and the elbow derivatives.

a) The infrazonal group

In the sheep only the sterno-scapularis is present in this group. This muscle was observed medial to the anterior portion of the superficial pectoral in all animals dissected. Its origin is on the ventral border of the anterior part of the sternum, and it is inserted into the brachiocephalicus just below the shoulder joint. It is a rather small, flat muscle. Howell (1944) says this muscle is used in fixation and is unimportant in locomotion. The means and analyses of variance for this muscle appear in Tables 88 and 89.

TABLE 88

MEANS FOR THE
STERNO-SCAPULARIS MUSCLE

Measurement	Breed Type		Treatment		S.E.
	Romney	Cheviot	Fresh	Fixed	
Weight (gm)	21.3	19.2	19.3	21.1	1.18
Length (cm)	8.9	8.2	8.8	8.4	0.14
Width (cm)	5.6	6.3	5.6	6.3	0.30
Depth (cm)	0.83	0.88	0.75	0.97	0.05
Area (sq cm)	36.8	36.7	35.7	37.8	1.24

The means in Table 88 show the Romney group to have the higher average weight and length while the Cheviots have a larger average width measurement. Hance, the average sterno-scapularis of the Romney group is longer and narrower in shape when compared with the same muscle in the Cheviot group.

TABLE 89

ANALYSES OF VARIANCE
FOR THE STERNO-SCAPULARIS MUSCLE

Source	d.f.	SS	MS	F
		For Weight		
Total	11	95.07	-	
Between treatments	1	11.41	11.41	1.36
Between breeds	1	13.44	13.44	1.61
Interaction	1	3.31	3.31	
Error	8	66.91	8.36	
		For Length		
Total	11	3.04	-	
Between treatments	1	0.66	0.66	5.84 *
Between breeds	1	1.47	1.47	13.00 **
Interaction	1	0.01	0.01	
Error	8	0.90	0.11	
		For Width		
Total	11	7.19	-	
Between treatments	1	1.14	1.14	2.12
Between breeds	1	1.14	1.14	2.12
Interaction	1	0.61	0.61	1.13
Error	8	4.30	0.54	
		For Depth		
Total	11	0.269	-	
Between treatments	1	0.141	0.141	10.91 *
Between breeds	1	0.008	0.008	
Interaction	1	0.008	0.008	
Error	8	0.103	0.013	
		For Area		
Total	11	88	-	
Between treatments	1	14	14	1.51
Between breeds	1	0	0	
Interaction	1	0	0	
Error	8	74	9.3	

In the analyses of variance in Table 89, however, only the length difference is significant.

The treatment comparison shows the fixed muscles to be the heavier, wider and deeper while the freshly slaughtered group have the longer. This is undoubtedly due, in part, to the new position assumed by the fore leg when the carcass is hung up. As may be seen from the analyses of variance, treatment exerts a significant effect only in the case of length and depth.

b) The shoulder derivatives of the ventral division

In most ungulates, this group is divided into three sections:- the pectoral matrix, the anterior coracoid matrix and the posterior coracoid matrix.

1) The pectoral matrix

In Howell's (1936) classification there are two muscles in this group. They are the deep pectoral and the panniculus carnosus. In this study the latter was omitted.

The deep pectoral is another of the muscles connecting trunk to limb and its main function is to provide locomotive power rather than to bind the limb to the body. In the sheep it is a broad, sling-shaped muscle with a broad origin on the abdominal tunic and along the posterior part of the ventral aspect of the sternum. The deep pectoral is inserted on both the lateral and medial tuberosities of the humerus. It has great power in drawing the trunk forward if the limb is advanced and fixed, by giving a strong downward and backward pull on the humerus. It is by far the larger of the two pectoral muscles.

The means in Table 90 indicate that the deep pectoral muscle on the Cheviot is a little longer, narrower and deeper. However, in no case does the mean difference approach significance except in the depth measurement.

TABLE 90

MEANS FOR
THE DEEP PECTORAL MUSCLE

Measurement	Breed Type		Treatment		S.E.
	Romney	Cheviot	Fresh	Fixed	
Weight (gm)	174.0	175.0	167.1	181.8	5.97
Length (cm)	33.1	34.3	34.2	33.3	0.64
Width (cm)	12.0	11.3	10.8	12.5	0.38
Depth (cm)	2.15	2.53	1.67	3.02	0.13
Area (sq cm)	274.1	265.6	262.5	277.3	7.50

Treatment, however, exerts a significant effect on width and depth since the fixed muscles are wider and deeper. The length is greater in the freshly dissected group which is an effect opposite to that which occurred with the brachio-cephalicus as a result of the carcass hanging up overnight. The limb being thus rotated forward would cause the deep pectoral to flatten, lengthen and become more narrow. It must not be reasoned, however, that this is the only or main reason for the changes in the muscle.

2) The anterior coracoid matrix

Howell's (1936) classification places three of the muscles of the sheep into this section:- the superficial pectoral, the supraspinatus and the infraspinatus.

a) The superficial pectoral

In the sheep this muscle is clearly divisible into two parts:- the relatively thick and short anterior part and the broad and very thin posterior section. In this dissection the muscle was removed and measured *in toto*. Its origin is along the ventral border of the sternum. Due to the spreading

TABLE 91

ANALYSES OF VARIANCE
FOR THE DEEP PECTORAL MUSCLE

Source	d.f.	SS	MS	F
For Weight				
Total	11	2417	-	
Between treatments	1	645	645	3.01
Between breeds	1	3	3	
Interaction	1	56	56	
Error	8	1713	214	
For Length				
Total	11	28.16	-	
Between treatments	1	2.80	2.80	
Between breeds	1	4.07	4.07	1.64
Interaction	1	1.49	1.49	
Error	8	19.80	2.48	
For Width				
Total	11	20.56	-	
Between treatments	1	8.17	8.17	9.50 *
Between breeds	1	1.54	1.54	1.79
Interaction	1	3.96	3.96	4.60
Error	8	6.89	0.86	
For Depth				
Total	11	7.11	-	
Between treatments	1	5.47	5.47	57.66 **
Between breeds	1	0.44	0.44	4.64
Interaction	1	0.44	0.44	4.64
Error	8	0.76	0.095	
For Area				
Total	11	3765	-	
Between treatments	1	660	660	1.95
Between breeds	1	216	216	
Interaction	1	185	185	
Error	8	2704	338	

nature of the superficial pectoral it has two main insertions;- (1) the fascia of the fore-arm and (2) the deltoid tuberosity of the humerus. Its action in addition to that of tensing the fascia of the fore-arm is to assist in adducting the arm.

TABLE 92

MEANS FOR
THE SUPERFICIAL PECTORAL MUSCLE

Measurement	Breed Type		Treatment		S.E.
	Romney	Cheviot	Fresh	Fixed	
Weight (gm)	57.2	59.8	53.3	63.7	3.56
Length (cm)	19.2	18.9	18.4	19.8	0.42
Width (cm)	10.8	10.5	11.0	10.3	0.08
Depth (cm)	1.17	1.28	1.10	1.35	0.07
Area (sq cm)	136.2	128.7	131.8	133.0	3.36

TABLE 93

ANALYSES OF VARIANCE
FOR THE SUPERFICIAL PECTORAL MUSCLE

Source	d.f.	SS	MS	F
For Weight				
Total	11	965	-	
Between treatments	1	320	320	4.19
Between breeds	1	21	21	
Interaction	1	13	13	
Error	8	611	76	
For Length				
Total	11	15.73	-	
Between treatments	1	5.61	5.61	5.10
Between breeds	1	0.34	0.34	
Interaction	1	0.95	0.95	
Error	8	8.83	1.10	
For Width				
Total	11	6.16	-	
Between treatments	1	1.60	1.60	44.44 **
Between breeds	1	0.37	0.37	10.28 *
Interaction	1	3.90	3.90	108.33 **
Error	8	0.29	0.04	

TABLE 93 (Continued)

Source	d.f.	SS	MS	F
For Depth				
Total	11	0.483	-	
Between treatments	1	0.188	0.188	6.09 *
Between breeds	1	0.041	0.041	1.31
Interaction	1	0.008	0.008	
Error	8	0.247	0.031	
For Area				
Total	11	969	-	
Between treatments	1	4	4	
Between breeds	1	168	168	2.47
Interaction	1	353	353	5.19
Error	8	544	68	

In this muscle the Cheviots have the larger mean weight (shown in Table 92) and the greater mean depth, while the Romneys are greater in the other measurements. None of these, as will be explained below, are significant.

The averages in Table 92 show the fixed group to be the larger in every case except width.

In the width measurement, interaction shows up to a marked degree, and this, in part, results in some interaction in the case of area. This means that the treatment had opposite effects on the different breed types. Since the posterior part of this muscle is very thin and pliable, it was very easy to stretch it out of its proper shape even in the course of normal handling. Also in the width measurement, the anterior head of this muscle was sometimes wider and other times the posterior section had the larger width measurement. This is the most logical explanation of the large interaction. Since the interaction is so large, it would be best to disregard the fact that breed and treatment seemingly show significant differences.

b) The supraspinatus

This is a relatively large muscle which, in the sheep, more than fills the supraspinous fossa of the scapula. This fossa and the anterior surface of the tuber spinae of the scapula are the origin of this muscle, and it is inserted mainly on the lateral tuberosity of the humerus on its anterior aspect. Its action is to extend the shoulder joint as well as to aid in the binding of this joint to help prevent dislocation.

TABLE 94

MEANS FOR
THE SUPRASPINATUS MUSCLE

Measurement	Breed Type		Treatment		S.E.
	Romney	Cheviot	Fresh	Fixed	
Weight (gm)	153.0	153.2	142.7	163.5	6.66
Length (cm)	16.7	16.8	16.5	16.9	0.32
Width (cm)	6.5	6.4	6.5	6.4	0.18
Depth (cm)	3.43	3.37	3.05	3.75	0.12
Area (sq cm)	72.7	72.2	70.7	74.2	1.82

There is practically no difference between the breed types in any of the measurements taken on the supraspinatus.

However, in the treatment means (Table 94), the fixed muscles show up with a slightly greater weight and present a significantly greater depth. Interaction does not show up to any marked degree in any of the items.

c) The infraspinatus

This muscle is the larger of the two that originate on the lateral fossae of the scapula. In the sheep studied it filled the infraspinous fossa with no overlapping of the posterior border of the scapula. It is inserted into a large

TABLE 95

ANALYSES OF VARIANCE
FOR THE SUPRASPINATUS MUSCLE

Source	d.f.	SS	MS	F
		For Weight		
Total	11	3421	-	
Between treatments	1	1302	1302	4.89
Between breeds	1	0	0	
Interaction	1	347	347	1.41
Error	8	2129	266	
		For Length		
Total	11	5.69	-	
Between treatments	1	0.61	0.61	
Between breeds	1	0.02	0.02	
Interaction	1	0.14	0.14	
Error	8	4.85	0.61	
		For Width		
Total	11	1.69	-	
Between treatments	1	0.05	0.05	
Between breeds	1	0.01	0.01	
Interaction	1	0.09	0.09	
Error	8	1.54	0.19	
		For Depth		
Total	11	2.22	-	
Between treatments	1	1.47	1.47	17.09 **
Between breeds	1	0.01	0.01	
Interaction	1	0.09	0.09	1.05
Error	8	0.65	0.08	
		For Area		
Total	11	207	-	
Between treatments	1	37	37	1.85
Between breeds	1	0	0	
Interaction	1	9	9	
Error	8	161	20	

tendon that connects onto the lateral tuberosity of the humerus (posterior to the insertion of the supraspinatus). Its functions include the abduction of the arm and the fixing of the shoulder joint to help prevent dislocation.

TABLE 96

MEANS FOR
THE INFRASPINATUS MUSCLE

Measurement	Breed Types Romney	Breed Types Cheviot	Treatment Fresh	Treatment Fixed	S.E.
Weight (gm)	162.8	180.0	161.7	182.0	7.50
Length (cm)	17.6	18.4	17.1	18.9	0.32
Width (cm)	8.5	8.7	8.2	8.9	0.30
Depth (cm)	2.55	2.97	2.40	2.98	0.31
Area (sq cm)	106.5	114.3	103.8	117.0	2.92

TABLE 97

ANALYSES OF VARIANCE
FOR THE INFRASPINATUS MUSCLE

Source	d.f.	SS	MS	F
For Weight				
Total	11	5352	-	
Between treatments	1	1241	1241	3.67
Betwwen breeds	1	972	972	2.88
Interaction	1	432	432	1.28
Error	8	2707	338	
For Length				
Total	11	16.97	-	
Between treatments	1	9.84	9.84	16.00 **
Between breeds	1	2.14	2.14	3.48
Interaction	1	0.07	0.07	
Error	8	4.92	0.615	
For Width				
Total	11	5.73	-	
Between treatments	1	1.34	1.34	2.53
Between breeds	1	0.17	0.17	
Interaction	1	0.00	0.00	
Error	8	4.23	0.529	
For Depth				
Total	11	1.73	-	
Between treatments	1	1.02	1.02	17.75 **
Between breeds	1	0.24	0.24	4.17
Interaction	1	0.01	0.01	
Error	8	0.46	0.058	

TABLE 97 (Continued)

Source	d.f.	SS	MS	F
		For Area		
Total	11	1173	-	
Between treatments	1	520	520	10.20 *
Between breeds	1	184	184	3.61
Interaction	1	61	61	1.20
Error	8	408	51	

In this muscle, the Cheviot group has the larger average in every measurement. None of these differences are significant although those of length, depth and area have mean squares that are between the ten and five per cent level of probability.

The formal saline fixed muscles have a bigger average in every case, but only the measurements of length, depth and area are significantly larger.

3) The posterior coracoid matrix

In the sheep only one small muscle is included in this section. Windle and Parson (1901) believe that, in the sheep, it is the coraco-brachialis medius. This muscle has its origin on the coracoid process of the scapula and is inserted on the humerus anterior to the teres tubercle. It assists in adduction of the arm and in the flexing of the shoulder joint. The means and analyses of variance for this muscle appear in Tables 98 and 99.

The means (in Table 98) show that this muscle is heavier and shorter in the Cheviot group, while width is about the same for both groups. However, this extra weight is made up in greater thickness in the Cheviot group. The area is about

TABLE 98

MEANS FOR
THE CORACO-BRACHIALIS MUSCLE

Measurement	Breed Type		Treatment		S.E.
	Romney	Cheviot	Fresh	Fixed	
Weight (gm)	9.4	10.8	9.9	10.2	0.67
Length (cm)	9.2	8.4	9.0	8.7	0.22
Width (cm)	3.4	3.3	3.2	3.5	0.12
Depth (cm)	0.87	1.05	1.02	0.90	0.05
Area (sq cm)	18.1	18.1	17.4	18.9	1.14

TABLE 99

ANALYSES OF VARIANCE
FOR THE CORACO-BRACHIALIS MUSCLE

Source	d.f.	SS	MS	F
For Weight				
Total	11	29.46	-	
Between treatments	1	0.21	0.21	
Between breeds	1	5.88	5.88	2.18
Interaction	1	1.77	1.77	
Error	8	21.61	2.70	
For Length				
Total	11	4.46	-	
Between treatments	1	0.24	0.24	
Between breeds	1	2.00	2.00	7.19 *
Interaction	1	0.00	0.00	
Error	8	2.22	0.28	
For Width				
Total	11	1.20	-	
Between treatments	1	0.34	0.34	3.95
Between breeds	1	0.02	0.02	
Interaction	1	0.15	0.15	
Error	1	0.69	0.09	
For Depth				
Total	11	0.269	-	
Between treatments	1	0.041	0.041	2.72
Between breeds	1	0.101	0.101	6.72 *
Interaction	1	0.008	0.008	
Error	8	0.120	0.015	

TABLE 99 (Continued)

Source	d.f.	SS	MS	F
		For Area		
Total	11	73.86	-	
Between treatments	1	6.75	6.75	
Between breeds	1	0.01	0.01	
Interaction	1	5.07	5.07	
Error	8	62.03	7.75	

the same in both groups, but since length and depth are different, a slight difference in form is indicated. The differences in length and depth measurements are the only ones that are significant.

The averages in the treatment comparisons are very close except for width and in this case the fixed group is more narrow. However, the difference in non-significant.

c) The elbow derivatives of the ventral division

This group consists of two muscles whose chief action is to flex the elbow joint. They are the brachialis and the biceps brachii.

1) The brachialis

This muscle spirals around the humerus from its origin just posterior to the surgical neck of that bone. Its insertion is on the medial surface of the neck of the radius and on the adjacent portion of the ulna. Its function, as mentioned above, is to flex the elbow joint.

In this muscle, a comparison of the means in Table 100 for breed types and treatments reveals no differences.

TABLE 100

MEANS FOR
THE BRACHIALIS MUSCLE

Measurement	Breed Types		Treatment		S.E.
	Romney	Cheviot	Fresh	Fixed	
Weight (gm)	24.8	24.5	24.4	24.9	1.46
Length (cm)	11.0	11.0	11.0	11.1	0.22
Width (cm)	4.0	4.1	4.1	4.0	0.08
Depth (cm)	1.17	1.22	1.18	1.20	0.04
Area (sq cm)	32.5	31.9	31.7	32.8	1.15

TABLE 101

ANALYSES OF VARIANCE
FOR THE BRACHIALIS MUSCLE

Source	d.f.	SS	MS	F
		For Weight		
Total	11	111.16	-	
Between treatments	1	0.70	0.70	
Between breeds	1	0.29	0.29	
Interaction	1	8.73	8.73	
Error	8	102.42	12.80	
		For Length		
Total	11	2.49	-	
Between treatments	1	0.02	0.02	
Between breeds	1	0.01	0.01	
Interaction	1	0.14	0.14	
Error	8	2.32	0.29	
		For Width		
Total	11	0.45	-	
Between treatments	1	0.01	0.01	
Between breeds	1	0.08	0.08	2.13
Interaction	1	0.06	0.06	1.60
Error	8	0.30	0.038	

TABLE 101 (Continued)

Source	d.f.	SS	MS	F
		For Depth		
Total	11	0.109	-	
Between treatments	1	0.002	0.002	
Between breeds	1	0.007	0.007	
Interaction	1	0.008	0.008	
Error	8	0.083	0.010	
		For Area		
Total	11	68.31	-	
Between treatment	1	3.85	3.85	
Between breeds	1	1.07	1.07	
Interaction	1	1.07	1.07	
Error	8	63.32	7.92	

2) The biceps brachii

Howell (1936) states that this muscle was derived from the brachialis. It lies on the ventral side of the humerus in the ungulate and has a tendinous origin on the tuber scapulae. In the sheep its insertion is a tendon that divides into two parts. One part attachs to the radial or bicipital tuberosity of the radius and the other part to the adjacent portion of the ulna, (Sisson, 1930). The action of the biceps in locomotion is to flex the elbow joint.

TABLE 102

MEANS FOR
BICEPS BRACHII MUSCLE

Measurement	Breed Type		Treatment		S.E.
	Romney	Cheviot	Fresh	Fixed	
Weight (gm)	36.3	37.7	36.7	37.3	1.82
Length (cm)	10.0	9.8	9.4	10.4	0.20
Width (cm)	3.0	3.1	3.2	3.0	0.08
Depth (cm)	2.63	2.67	2.55	2.75	0.10
Area (sq cm)	24.0	23.2	22.9	24.3	0.75

TABLE 103

ANALYSES OF VARIANCE
FOR THE BICEPS BRACHII MUSCLE

Source	d.f.	SS	MS	F
		For Weight		
Total	11	166	-	
Between treatments	1	1	1	
Between breeds	1	5	5	
Interaction	1	2	2	
Error	8	158	20	
		For Length		
Total	11	4.72	-	
Between treatments	1	2.71	2.71	11.53 **
Between breeds	1	0.07	0.07	
Interaction	1	0.06	0.06	
Error	8	1.88	0.24	
		For Width		
Total	11	0.47	-	
Between treatments	1	0.12	0.12	2.93
Between breeds	1	0.02	0.02	
Interaction	1	0.00	0.00	
Error	8	0.33	0.04	
		For Depth		
Total	11	0.640	-	
Between treatments	1	0.070	0.070	
Between breeds	1	0.015	0.015	
Bnteraction	1	0.164	0.164	2.89
Error	8	0.454	0.057	
		For Area		
Total	11	35.21	-	
Between treatments	1	5.46	5.46	1.61
Between breeds	1	2.16	2.16	
Interaction	1	0.38	0.38	
Error	8	27.21	3.40	

A comparison of the breed type means (Table 102) reveals no difference between the groups. A treatment difference does show, however, in length, the muscle being significantly longer in the fixed group. When the carcasses were hung up, it was noted that the elbow joint became somewhat flexed. This would compress the biceps brachii to some degree and could possibly shorten its length.

A summary of the significant differences in the muscles between the two breed types and between the two treatments is given in Tables 103 and 104. In these tables one symbol indicates significance to the five per cent level and two symbols indicates significance to the one per cent level of probability.

TABLE 103

SUMMARY OF SIGNIFICANT DIFFERENCES
BETWEEN BREED TYPES

Muscle	Weight	Length	Width	Depth	Area
Trapezius					
Brachiocephalicus + omo-trans.				*	
Serratus thoracis		**			
Rhomboideus					
Latissimus dorsi					
Teres major	*		*	**	*
Subscapularis					
Teres minor				*	*
Deltoideus pars acromialis	**		**		**
Deltoideus pars scapularis					
Tensor fasciae antibrachii					
Anconeus	*		*		
Triceps brachii (long head)		*			
Triceps brachii (lateral head)	*	**			
Triceps brachii (medial head)	*				*
Sterno-scapularis		x			
Superficial pectoral			x		
Deep pectoral					
Supraspinatus					
Infraspinatus					
Coraco-brachialis		x		*	
Brachialis					
Biceps brachii					

* equals Cheviots greater
x equals Romneys greater

TABLE 104

SUMMARY OF SIGNIFICANT DIFFERENCES
BETWEEN TREATMENTS

Muscle	Weight	Length	Width	Depth	Area
Trapezius		xx	**		**
Brachiocephalicus+omo-trans.	*	**	*		**
Serratus thoracis			**		*
Rhomboideus					
Latissimus dorsi			**	**	
Teres major	*	*			
Subscapularis					*
Teres minor		**		**	*
Deltoideus pars acromialis		**			**
Deltoideus pars scapularis		**		*	*
Tensor fasciae antibrachii					
Anconeus				*	
Triceps brachii (long head)		**			
Triceps brachii (lateral head)				**	
Triceps brachii (medial head)					
Sterno-scapularis		x			*
Deep pectoral			*	**	
Superficial pectoral			xx	*	
Supraspinatus				**	
Infraspinatus		**		**	*
Coraco-brachialis					
Brachialis					
Biceps brachii					

* equals fixed muscles greater
x equals fresh muscles greater

F. The Volumes of Certain Muscles

The measurement of muscle volume is considered to be of doubtful accuracy because of certain unavoidable errors in the technique used. Factors which served to introduce error into the actual measurement were as follows:-

a) Small air bubbles on the surface of the muscles when immersed. These were cause by the somewhat greasy surface of the muscles and once the muscle was immersed, it was impossible to get rid of these bubbles.

b) It is possible that the surface tension was not equally decreased each time. This would result in a small difference in amount of over-flow.

c) The possibility of absorption of water into the muscle during immersion. This factor could also very easily be different in the fresh and fixed muscles.

d) Varying sizes of muscles. Smaller muscles were more difficult to handle. For these, use of a smaller apparatus would have cut down error.

A further error resulting from temperature changes causing changes in the weight of a cubic centimetre of water was considered to be negligible. At four degrees centigrade, one cubic centimetre of water weighs one gram; at twenty degrees centigrade, it weighs 1.0018 grams.

It was impossible to make repeat measurements for any one particular muscle because re-immersion would introduce further error due to water absorption and because of the presence of a water film on the surface of the muscle left by a previous immersion. Furthermore, if time were allowed for this water film to evaporate, it would be almost impossible to dry the muscle back to its previous state.

From the above difficulties it will be deduced that any figures obtained for muscle volume would only be an approximation.

In order to make a rough comparison between breed types and treatments for muscle volume as determined by immersion, the following procedure was adopted:- The twelve muscles that had the highest average weight (all those over 50 grams) were listed and a list of these in each animal presenting their weights and volumes (in grams) was constructed. These muscles were:-

Latissimus dorsi	Superficial pectoral
Infraspinatus	Deep pectoral
Supraspinatus	Rhomboideus
Subscapularis	Serratus thoracis
Triceps brachii	Muscles of the fore-arm
Trapezius	Brachiocephalicus + omo-transversarius

Thus, total weights and volumes of the above muscles were available for each animal in the dissection groups. From the animal totals an analysis of variance was applied to compare breed types and treatments. Also from the animal total of muscle weights (grams) and of muscle volume (grams), the ratios of volume to weight were worked out. Thus, it is hoped that an approximate figure may be presented which will give an indication of the amount of water displaced by the muscles analysed. Muscle volume expressed as a percentage of muscle weight is shown in Table 105 and the analysis of variance for volume totals appears in Table 106.

The percentages shown in Table 105 do not indicate any breed difference, but do show that treatment had a slight effect.

TABLE 105

MUSCLE VOLUME
EXPRESSED AS A PERCENTAGE OF MUSCLE WEIGHT

	Romney		Cheviot	
	Fresh	Fixed	Fresh	Fixed
	96.32 %	97.79 %	95.99 %	95.77 %
	96.26	97.47	95.69	97.20
	94.81	96.79	95.58	96.97
Mean	95.97	97.35	95.75	96.65

It appears that the total for the freshly dissected muscles listed was between one and 1.5 per cent less in volume than the total for the same muscles dissected from the fixed sheep. That this difference is not significant is borne out by the analysis of variance in Table 106.

TABLE 106

ANALYSIS OF VARIANCE
FOR MUSCLE VOLUME TOTALS

Source	d.f.	SS	MS	F
Total	11	218.99	-	
Between treatments	1	62.50	62.50	3.50
Between breeds	1	1.67	1.67	
Interaction	1	12.14	12.14	
Error	8	142.77	17.85	

The slight treatment apparent in Table 106 can either be attributed to a shrinking of the fresh muscles or to a swelling of the fixed muscles. Probably, it is a combination of the two.

G. Bone, Muscle and Fat Proportions

The technique used in dissection provided an excellent opportunity to obtain information on the ratio of bone, muscle and fat in the shoulder region. While the dissection technique was not the same as that of Hammond's (1932) and Palsson's (1940), it followed well-defined lines in the region dissected and was done in the same manner in all animals. Certainly, there was no error of the type that would occur when the carcass is jointed to obtain a "Sample Joint". As pointed out previously, the muscles concerned were weighed whole and the bones were weighed immediately after dissection and cleaning of cartilage and ligaments. The fat measured was that amount removed from the area directly lateral to the most medial muscles dissected in an area. (For example, fat weighed in the area in which the rhomboideus was placed would include all fat lateral to this muscle whether inter-muscular fat or subcutaneus fat.) If a dissected muscle was the deepest of the muscles removed in the region from whence it came, the fat on its medial side would not be weighed, although this fat had to be removed from that muscle in order to get its true weight. The muscle tendons were included with the fat. The fat was weighed at intervals throughout the dissection process, so that it would not have the opportunity to lose weight by drying out. The one exception to this fat removal was in the case of panniculus carnosus muscle which was reflected along with the small amount of fat lateral to it. Although the muscles of the fore-arm (those around the radius-ulna) were not dissected muscle by muscle, the bone, muscle and fat tissue were separated and these figures are included in the calculations.

With the above procedure applied to the three components involved in the bone, muscle and fat ratio, a fairly accurate comparison could be made between the groups of animals studied. The means and the analyses of variance for these tissue totals appear in Tables 107 and 108.

TABLE 107

MEANS FOR
THE BONE, MUSCLE AND FAT TOTALS

Item	Breed Types		Treatment		S.E.
	Romney (grams)	Cheviot (grams)	Fresh (grams)	Fixed (grams)	
Bone (including cartilage of scapula)	291	279	283	287	13.7
Muscle	1807	1862	1762	1906	64.4
Fat (including tendon and fascia)	852	470	670	652	65.9
Total tissue dissected	2950	2611	2715	2845	130.3

In the table of means (Table 107) it may be noted that the Romney group has the higher average weight of total tissue dissected and weighed in this study. However, when the analysis of variance is applied, it is found that this mean difference is not significant. This is largely a result of the high variability within breed types as indicated by the standard error. There seems to be a tendency for the Romney group to be heavier as the F value for the mean square between breeds comes up to the ten per cent level of probability.

The bone weights of those dissected and weighed are

TABLE 108

ANALYSES OF VARIANCE
FOR DISSECTED TISSUES

Source	d.f.	SS	MS	F
For Bone				
Total	11	9954	-	
Between treatments	1	38	38	
Between breeds	1	481	481	
Interaction	1	434	434	
Error	8	9001	1125	
For Muscle				
Total	11	285806	-	
Between treatments	1	61877	61877	2.49
Between breeds	1	9070	9070	
Interaction	1	15956	15956	
Error	8	198894	24861	
For Fat				
Total	11	767500	-	
Between treatments	1	1032	1032	
Between breeds	1	435877	435877	16.74 **
Interaction	1	122263	122263	4.70
Error	8	208328	26041	
For Total Tissue				
Total	11	1273307	-	
Between treatments	1	49665	49665	
Between breeds	1	346120	346120	3.40
Interaction	1	62209	62209	
Error	8	815313	101914	

very similar with the Romney group having a slightly larger mean. This difference proves to be non-significant.

The average muscle weight shows the opposite trend to that of the bone weight, the Cheviot group being slightly higher in average weight of this tissue. Again, the breed difference is non-significant.

For the weight of fat, however, the Romney types had roughly twice as much fat by weight per animal in the shoulder region. When the analysis of variance is applied to the animal totals for fat, it is found that this difference between breed types is highly significant. Although separate weights were not taken of subcutaneous fat and inter-muscular fat, it appeared that the greater amount of fat in the Romneys was due to a thicker layer of subcutaneous fat. In looking for a reason for this difference in fat, a check was made into the life histories of the ewes dissected in order to see if they had produced a lamb or lambs in the lambing season prior to this study. This search revealed that two of the six Romneys had been dry, but a check of the fat figures for these two ewes showed that one was above the Romney group average and the other below so that they cancelled each other. In other words the higher fat condition of the Romney group was very little, if at all affected by the two dry ewes. As a point of interest, it was discovered that all of the Cheviot type ewes had produced a lamb or lambs in the previous season.

The effect of the treatments is not marked in any of the tissues. The total tissue and the bone and fat have a little higher average in the fixed group and the fat has a slightly higher mean in the freshly dissected animals. The largest difference is found in the muscle tissue averages but this difference does not even approach significance.

If the amount of fat found in this region is any indication of fat in the rest of the body, it might be concluded that the higher average live weight of the Romney group was mainly due to greater amounts of fat rather than to either the bone or muscle tissue. In this regard, Shorland _et al_ (1947) state that the fat content of the thorax, loin, pelvis and shoulder are highly correlated with the total fat content of the carcass and that any one of the above mentioned regions can be used to estimate the total amount of this tissue in the carcass. This observation refers to New Zealand lamb and mutton. They go on to state that there was a high correlation between dissectable fat and fat determined chemically for both the carcass as a whole and for individual joints.

To further compare the effects of treatments and breed types on these tissue components, the percentage carcass composition in terms of bone, muscle and fat is presented in Table 109.

TABLE 109

PROPORTIONS OF
BONE, MUSCLE AND FAT
IN THE SHOULDER REGION

Item	Breed Type		Treatment	
	Romney	Cheviot	Fresh	Fixed
Bone	9.86 %	10.69 %	10.42 %	10.09 %
Muscle	61.25	71.31	64.90	66.99
Fat	28.89	18.00	24.68	22.92
Total	100.00	100.00	100.00	100.00

Table 109 shows that the greater amount of fat found in the Romneys affects quite considerably its percentage of the total tissue.

1. Muscle in relation to bone

In order to determine if any relation existed between weight of bone and the weight of muscle of the region dissected a correlation coefficient was calculated. The result was:- $\underline{r}$ (bone weight with muscle weight) is equal to +0.743. For eleven degrees of freedom this correlation coefficient is highly significant. Calculating the correlation coefficient is necessary, according to Leonard and Clarke (1939), in order to procede to the next step which is the computation of the regression. A scatter graph was constructed to illustrate the regression of muscle on bone and this will be found in Figure 39. It will be noted that with an increase in bone there is a corresponding increase in weight of muscle. The regression coefficient indicates that for every gram increase in bone there is 3.98 grams increase in muscle in the group studied. A $\underline{t}$ test was applied to the regression and this was found to be highly significantly different from zero.

2. Percentage of muscle to bone and fat to bone

The means for each breed type were used to calculate the percentage of muscle to bone to see if any marked difference existed. The percentage of muscle to bone in the Romney group was 608 per cent and in the Cheviot group, 674 per cent. In discussing this type of relationship, Hammond (1932) says that the proportion of muscle to bone is very much larger in the small unimproved breeds that he studied. He accounts for this in two ways:- firstly, that the increased muscular exercise in the wild types leads to greater muscular development and secondly, that the thickening of the bones in the improved mutton types leads to a reduction in the proportion of muscle to bone.

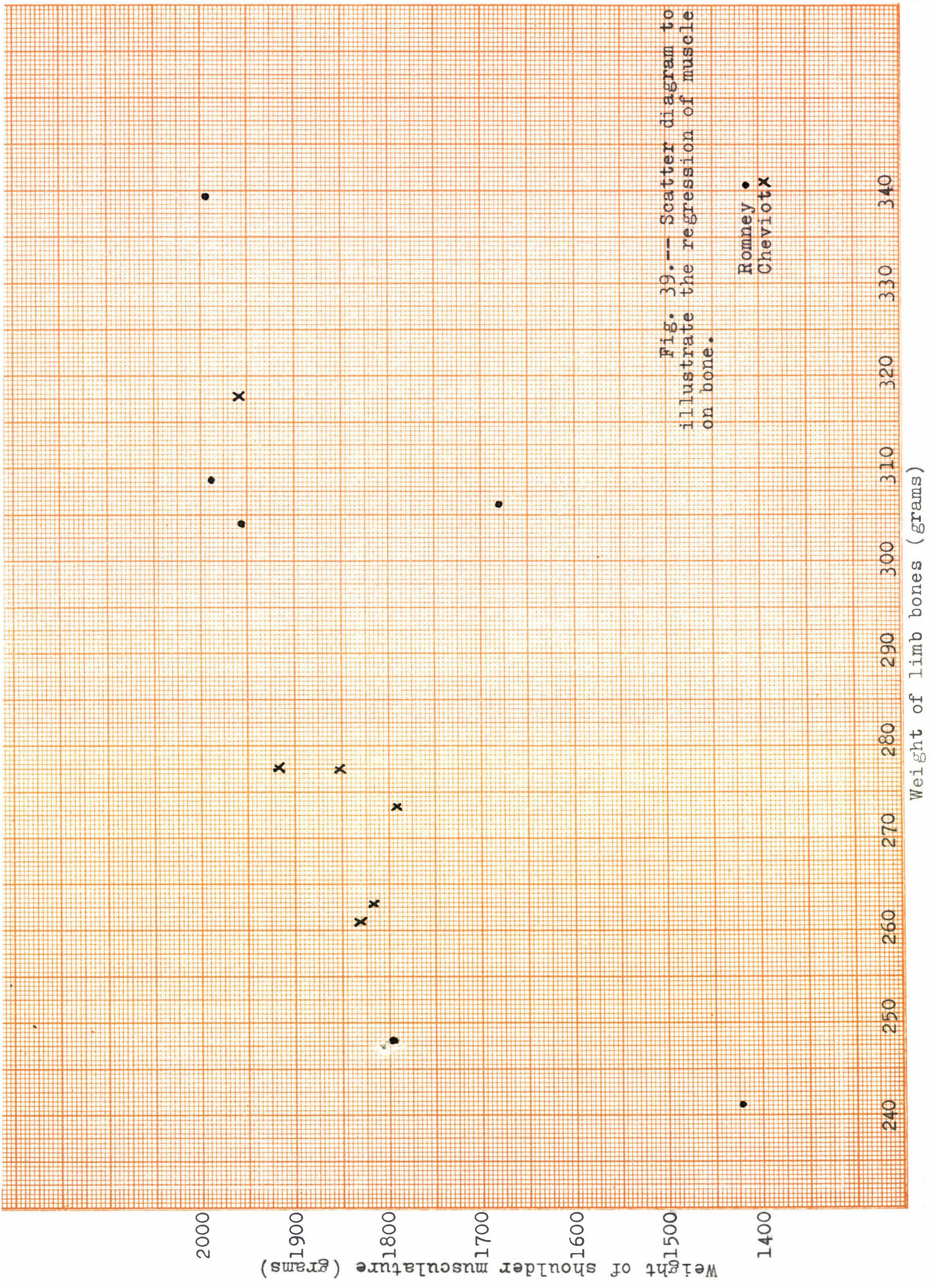


Fig. 39.-- Scatter diagram to illustrate the regression of muscle on bone.

The percentage of fat to bone was also calculated for the groups studied. The results are:- The Romney group, 293 per cent and the Cheviot group, 168 per cent. As mentioned before most of this difference appeared to be in the thicker layer of subcutaneous fat of the Romney group.

The above two facts if interpreted on the basis of Hammond's (1932) suggestions, would indicate the Romney group to be the more improved mutton type while the Cheviot group tends toward the semi-wild breeds.

H. Angulations

This section is presented under two main sub-headings:- (1) the angles formed between the long axes of the bones and the horizontal and (2) the angles formed between the long axis of one bone and the same axis on the adjoining bone.

1. The angles between the long axes of the bones and the horizontal

Since the living sheep, when being radiographed, were standing on the horizontal plane and the sides of the X-ray plate were parallel with this plane, these edges could be used as a base for the measurement of the above angles. The measurements were taken from the tracings of the radiographs made on architect's tracing paper as illustrated in Figure 41. The points of measurement,also shown in Figure 41, were selected because they were easily identified on all plates. The angles thus measured in this section are as follows:- (1) the angle between the posterior border of the scapula and the horizontal, (2) the angle between the long axis of the humerus and the horizontal (slope of the humerus), (3) the angle between a line along the ventral border of the thoracic vertebrae and the horizontal and (4) the angle between the radius-ulna line and the horizontal. The significance of differences between breed types was tested using the *t* test, the results being presented in Table 110.

The first two angles listed in Table 110 show no significant difference. Not only are the means close together, but the variability within breeds is quite high as evidenced by the

TABLE 110

MEANS FOR ANGLES
BETWEEN THE LONG AXES OF CERTAIN BONES AND THE HORIZONTAL

Angle	Breed Type	d.f.	Mean (degrees)	S.D.	S.E.	*t*
Between the scapula and horizontal	Romney	9	49.2	5.58	1.77	1.11 NS
	Cheviot	9	51.8	4.90	1.55	<0.3
Between the humerus and horizontal	Romney	9	133.8	7.06	2.23	1.10 NS
	Cheviot	9	137.3	7.21	2.28	<0.3
Between vertebrae and horizontal	Romney	9	17.1	5.02	1.59	3.20 **
	Cheviot	9	10.9	3.51	1.11	
Between radius-ulna and horizontal	Romney	9	68.0	5.06	1.60	2.49 **
	Cheviot	9	73.5	4.83	1.53	

relatively large standard deviation in each case. In discussing the angle between the horizontal and the plane of these two bones (the scapula and the humerus) Howell (1944) lists some unsubstantiated claims made in regard to them in the race horse. For instance, a relatively vertical scapula is supposed to help promote speed in the sprint and a horizontal humerus is said to favour speed. In addition, it is claimed that a sloping humerus naturally accompanies a vertical scapula. In the first two points, no differences are apparent in the sheep groups studied nor does a sloping humerus seem to be associated with a vertical scapula. They both slope at approximately ninty degrees to one another.

In the angle between the thoracic part of the vertebral column and the horizontal, in spite of the high standard deviation, a significant breed type difference is demonstrated. The Romney group has the larger average angle indicating that the thoracic portion of the vertebral column has a steeper slope. The Cheviot group had a vertebral column (thoracic section) that is more nearly parallel to the horizontal plane. This means a line along the dorsal tips of the thoracic spines in the Romney (in which the six anterior spines are significantly shorter) would be more nearly parallel to the horizontal than in the Cheviots. This difference undoubtedly contributes to the seemingly higher and more pointed withers of the Cheviot group.

The comparison between groups in the angle between the radius-ulna and the horizontal plane shows that the Cheviot group tends more towards being vertical in this bone. The difference is significant even though the within-group variability is high. The angles recorded should not be considered as the true angles between the long axis of the radius-ulna and the horizontal because the points located do not necessarily follow the true ventro-dorsal axis of the bone. The points were used because they could be spotted more easily on the radiographs and are satisfactory for comparing the two types.

The six animals that were formalin fixed were X-rayed in the manner described in Section III. Since these same animals had been X-rayed alive, a comparison was possible to show if any treatment difference existed. The means for this comparison and an analysis of variance appear in Table 111 and 112.

A comparison of the means of the breed types confirms the earlier finding in regards to the angles with the horizontal.

TABLE 111

MEANS SHOWING
BREED AND TREATMENT DIFFERENCES
IN CERTAIN ANGLES OF BONES
(DEGREES)

Angle	Breed Type		Treatment		S.E.
	Romney	Cheviot	Alive	Fixed	
Between the scapula and horizontal	48.3	49.0	52.3	45.0	1.49
Between the humerus and horizontal	131.0	135.2	140.0	126.2	1.35
Between vertebrae and horizontal	19.5	13.7	15.7	17.5	1.53
Between radius-ulna and horizontal	63.3	70.2	72.3	61.2	1.94

Again, the angle formed between the ventral border of the thoracic vertebrae and the horizontal and the angle between the radius-ulna and the horizontal are significanly different between breed types.

Inspection of the means in Table 111 in the treatment groups indicates an effect in every case, all of these being significant except the angle between the vertebral column and the horizontal plane. The technique used in the fixing of the animals resulted in a decrease in every angle. Such a decrease would occur if the humerus were rotated in a clockwise direction and the total distance between the proximal end of the scapula and the knee joint remained the same. Since the limb bones were not bearing the weight of the animal's body during the process of fixing, just such an action could feasibly occur. This is illustrated in an exaggerated form in

TABLE 112

ANALYSES OF VARIANCE
FOR CERTAIN ANGLES OF BONES

Source	d.f.	SS	MS	F
Angle Between the Scapula and the Horizontal				
Total	11	283	-	
Between treatments	1	162	162	12.10 **
Between breeds	1	2	2	
Interaction	1	11	11	
Error	8	107	13.4	
Angle Between the Humerus and the Horizontal				
Total	11	883	-	
Between treatments	1	574	574	52.18 **
Between breeds	1	52	52	4.73
Interaction	1	169	169	15.37 **
Error	8	87	11	
Angle Between the Vertebrae and the Horizontal				
Total	11	239	-	
Between treatments	1	10	10	
Between breeds	1	102	102	7.23 *
Interaction	1	14	14	
Error	8	113	14.1	
Angle Between the Radius-ulna and the Horizontal				
Total	11	724	-	
Between treatments	1	374	374	16.62 **
Between breeds	1	140	140	6.22 *
Interaction	1	30	30	1.33
Error	8	180	22.5	

the accompanying figure, Figure 40. The interaction variance present in the slope of the humerus indicates that the breeds reacted differently in this action. In other words it did not occur to the same extent in the Cheviot group as in the Romney group.

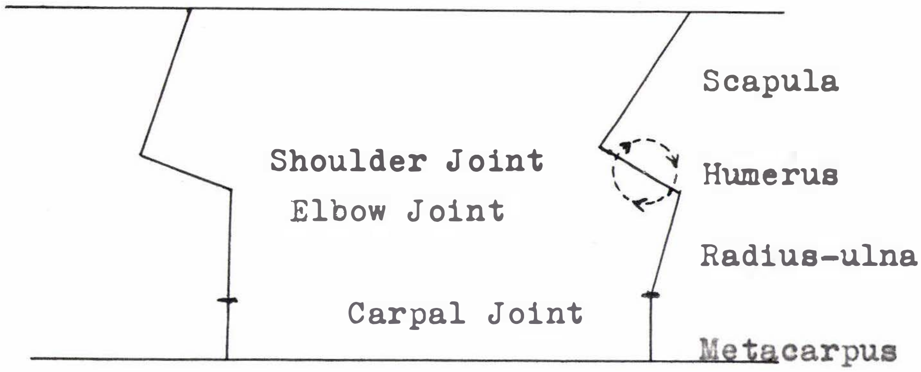


Fig. 43.--Line diagram showing the difference between the normal angles of the limb bones and those in an animal whose weight is off its feet (laying on its side as in the fixing process).

In order to determine whether there was any major change in the above angles caused by hanging the carcasses overnight, a representative carcass of each breed type was radiographed prior to dissection. The measurements taken from the X-ray plates of the carcasses are shown in Table 113.

TABLE 113

CERTAIN ANGLES FROM CARCASSES (DEGREES)

Breed Type	Betw. Scapula & Horizontal	Betw.Humerus & Horizontal	Betw.Vertebrae & Horizontal	Btw.Radius-ulna & Horizontal
Romney	28	112	18	41
Cheviot	29	100	16	36
Mean	29	106	17	39

A comparison between the three treatments:- live, fixed and carcass is shown in Table 114.

It will be noted from Table 114 that changes in the angles of the bones of the limb were greater between the fixed

TABLE 114

COMPARISONS OF CERTAIN ANGLES
BETWEEN THE LIVE, FIXED AND CARCASS

Treatment	Btw.Scapula & Horizontal	Btw.Humerus & Horizontal	Btw.Vertebrae & Horizontal	Btw. Radius-ulna & Horizontal
Live	50.5	135.6	14.0	70.8
Fixed	45.0	126.2	17.5	61.2
Carcasses	29.0	106.0	17.0	39.0

and carcass stage than from the live to the fixed state. In the carcasses the whole leg rotated in a clockwise direction, the scapula moving less than the humerus which, in turn, moved less than the radius-ulna. This is probably explained by the fact that there are more supporting connections of the limb to the trunk in the upper or dorsal section of the limb. This movement is illustrated by the tracings of the radiographs which appear in Figures 41 and 42.

2. <u>The angles between the long axes of the bones of the limb</u>

These are the angles formed between the long axes of the limb bones as the animal stands normally. The angles which could be measured were:- (1) the angle of the elbow joint (angle between the long axis of the humerus and the long axis of the radius-ulna), (2) the angle of the shoulder joint (angle between the posterior border of the scapula and the long axis of the humerus) and (3) the angle between the posterior border of the scapula and the ventral border of the thoracic section of the vertebral column.

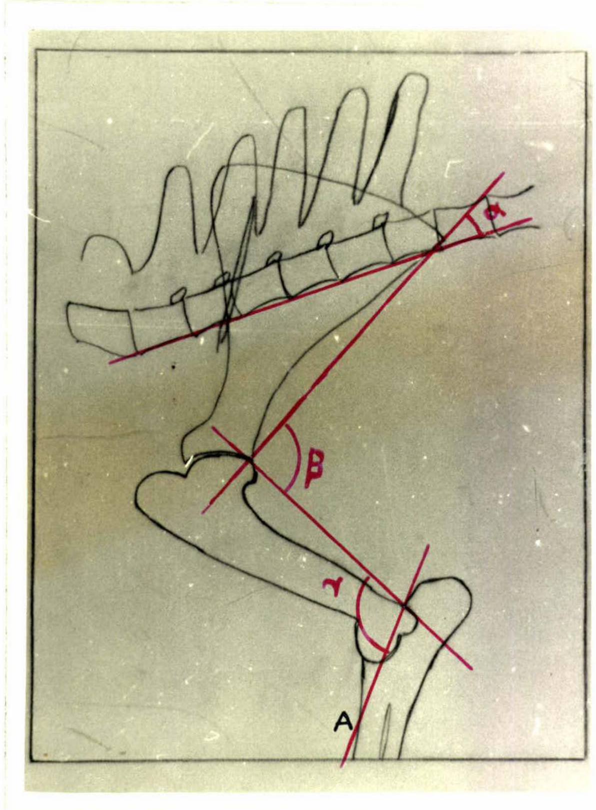


Fig. 41.--Tracing made from a radiograph of a live sheep. Alpha is the angle between the thoracic part of the vertebral column and the scapula; beta is the angle between the scapula and the humerus; gamma is the angle between the humerus and the radius-ulna. Point "A" is a point 4 cm. ventral to the antero-proximal edge of the radius.

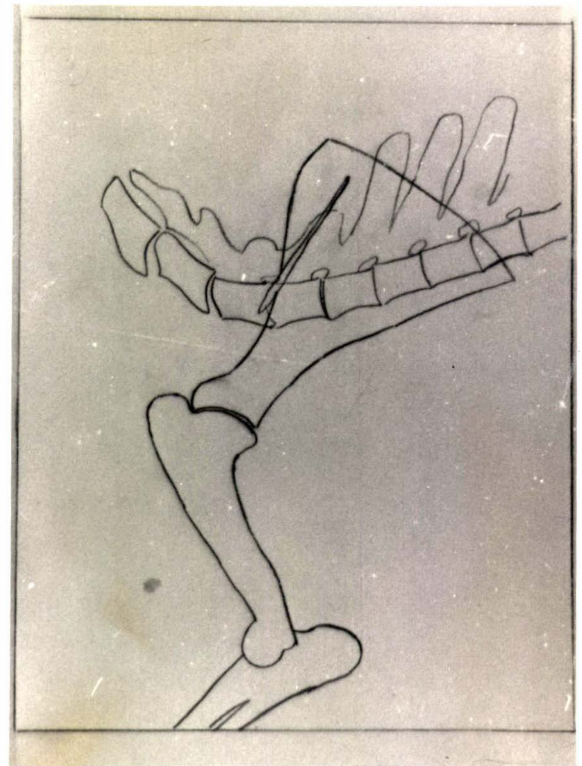


Fig. 42.--Tracing made from a radiograph of the carcass of the same animal represented in Figure 41. Prior to radiography the carcass had hung on a standard gambrel for a 15 hour period.

In comparing the above angles taken from the radiographs of the live animals, the *t* test was used. The results are presented in Table 115.

TABLE 115

ANGLES FORMED
BETWEEN THE LONG AXES OF CERTAIN BONES

Angle	Breed Type	D.F.	Mean (degrees)	S.D.	S.E.	*t*
Elbow joint	Romney	9	114.1	7.33	2.32	0.62 NS
	Cheviot	9	116.1	7.92	2.51	
Shoulder joint	Romney	9	96.2	6.80	2.15	0.52 NS
	Cheviot	9	94.7	5.94	1.88	
Between scapula and vertebrae	Romney	9	32.6	7.64	2.43	3.19 **
	Cheviot	9	41.8	4.94	1.56	

In the normal articulate angles formed in the shoulder joint and in the elbow joint there appears to be no real group difference (shown in Table 115). However, it will be noted that the Romney group has a slightly higher average angle of the shoulder joint while the Cheviot group has the greater average for the angle of the elbow joint.

A significant difference was found to exist between groups in the angle formed between the posterior border of the scapula and the vertebral column (thoracic part). The angle formed by the crossing of these lines is considerably smaller in the Romney group than in the Cheviot group. This occurs in spite of a relatively high variability within groups. As was found in the previous section, this difference is due more to the position of the vertebral column than to the scapula being more vertical in one of the groups.

In a study between breed types in horses, Bethcke (1930) found that the trotting horse has a smaller angle in the shoulder joint but a larger one in the elbow joint when compared with a cavalry horse and the thoroughbred. He studied 23 animals and found mean differences of only one degree. His conclusion, that that this is probably a functional adaptation difference should not be accepted as definite, because of the fact that the spread in his group of trotters for the elbow angle was ten degrees and for the shoulder angle, twelve degrees. As a point of interest, his figures for the trotters average 105 degrees for the shoulder angle and 144 degrees for the angle of the elbow joint, which means that, if this can be taken as typical of horses, the horse would have the appearance of being straighter in the leg than the sheep. The point is that, if Bethcke (1930) found little or no difference between two horse types having completely different functional training, it would be unlikely that there would be any within species difference between normal articulate angles unless, of course, there were a vast difference in body weight (or weight supported by the limbs).

In connection with the question of body weights, Osborn (1900) points out that the straightening of the limb is an adaptation designed to transmit the increasing weight through a vertical shaft. Thus, he cites the elephant, whose limbs support a great weight and whose limb columns are nearly vertical because of the large articulate angles of the limb bones. This permits the elephant to have only a kind of shuffling movement in its locomotion, whereas, in lighter animals, whose articulate angles more nearly approach ninty degrees, leaping, bounding and galloping are possible. Also on the same theme, Gregory (1912) points out that the bent or angulate character in the limbs of cursorial animals is correlated in part with very long, slender feet and with a bounding, galloping ortrotting gait, in combination with a long, very rapid stride of maximal acceleration increment. Not only does this apply to the long bones of the leg such as the radius-ulna and the metacarpus, but also to the distal end of the limb. With regard to the phalanges in the animals, Stillman (1882) states that the sudden straightening out of the bent pastern greatly assists in sending the animal body into the air.

The angles formed between the long bones were also measured on the radiographs of the fixed animals and compared with those of the same animal when alive. The means in this comparison and the analyses of variance appear in Tables 116 and 117.

TABLE 116

MEANS SHOWING
BREED AND TREATMENT DIFFERENCES IN CERTAIN ANGLES

Angle	Breed Type		Treatment		S.E.
	Romney (degrees)	Cheviot (degrees)	Alive (degrees)	Fixed (degrees)	
Elbow joint	113.7	115.3	113.8	115.2	2.20
Shoulder joint	97.8	94.7	93.2	99.3	1.55
Between scapula and vertebrae	29.2	35.8	37.5	27.5	3.89

TABLE 117

ANALYSES OF VARIANCE
FOR CERTAIN ANGLES BETWEEN LONG AXES OF BONES

Source	d.f.	SS	MS	F
For the Elbow Joint				
Total	11	509	-	
Between treatments	1	5	5	
Between breeds	1	8	8	
Interaction	1	275	275	9.48 *
Error	8	234	29	
For the Shoulder Joint				
Total	11	530	-	
Between treatments	1	114	114	7.92 *
Between breeds	1	30	30	2.08
Interaction	1	271	271	18.82 **
Error	8	115	14.4	
The Angle Between the Scapula and Vertebrae				
Total	11	1215	-	
Between treatments	1	300	300	3.31
Between breeds	1	133	133	1.47
Interaction	1	57	57	
Error	8	725	90.6	

The means in Table 116, of course, follow the same direction as noted in the live animals for the elbow joint and the angle between the scapula and the vertebrae. They are larger in the Cheviot group and the shoulder joint angle is larger in the Romney group. However, with these groups there are no significant breed type differences.

The fixed group has a larger elbow joint and shoulder joint angle and has a smaller angle between the scapula and the vertebrae. This is significant only in the case of the shoulder joint angle which appears to have been increased by the fixing treatment. Interaction is apparent in two cases, in the analysis for the elbow angle and in the analysis for the shoulder angle. This indicates that the breed groups did not respond in exactly the same manner to the fixing treatment.

The angles between the long bones were also measured on the radiographs of the two carcasses. These measurements are given in Table 118.

TABLE 118

CERTAIN ANGLES
TAKEN FROM RADIOGRAPHS OF CARCASSES

Breed Type	Angle of Elbow Joint (degrees)	Angle of Shoulder Joint (degrees)	Angle Btw.Scapula and Vertebrae (degrees)
Romney	116	110	13
Cheviot	109	95	11
Mean	113	102	12

The means in Table 118 were compared with those obtained from the other treatments. This comparison appears in Table 119.

TABLE 119

COMPARISON OF CERTAIN ANGLES
BETWEEN THE LIVE, FIXED AND CARCASS

Treatment	Angle of Elbow Joint (degrees)	Angle of Shoulder Joint (degrees)	Angle Btw.Scapula and Vertebrae (degrees)
Live	115.1	93.2	37.2
Fixed	115.2	99.3	27.5
Carcass	113.0	102.0	12.0

In the change from live to fixed the elbow joint remained about the same while the shoulder joint was extended to a limited extent (shown in Table 119). Also, the scapula rotated in a clockwise direction to some degree. As shown by the analysis of variance in Table 117, the extension of the shoulder joint was the only significant change. In comparing the angles between the bones in the carcass with the same angles in the live and fixed animals, it will be noted that the elbow joint closed to a limited extent while the shoulder joint extended slightly. The angle between the scapula and the vertebrae narrowed a great deal, indicating that the weight of the arm cause the scapula to rotate (about 25 degrees from the live state).

In order to illustrate any association existing between angles formed by the long bones in the same animal, a graph was constructed. The animals in each group were listed in the order of ascending or increasing angle of the elbow joint. This line was plotted and points representing the other two angles (the shoulder joint angle and the angle between the scapula and the vertebrae) were located and connected as shown in Figure 43. Although the last two mentioned lines are quite erratic, the graphing does show that when one of the angles is large, the other two will generally be greater in the same animal. The elbow angle and the shoulder angle are more closely correlated than any other combination of the three. The graph also illustrates the group difference between the angle between the scapula and the vertebrae. Correlation coefficients for the various angles appear in Table 120.

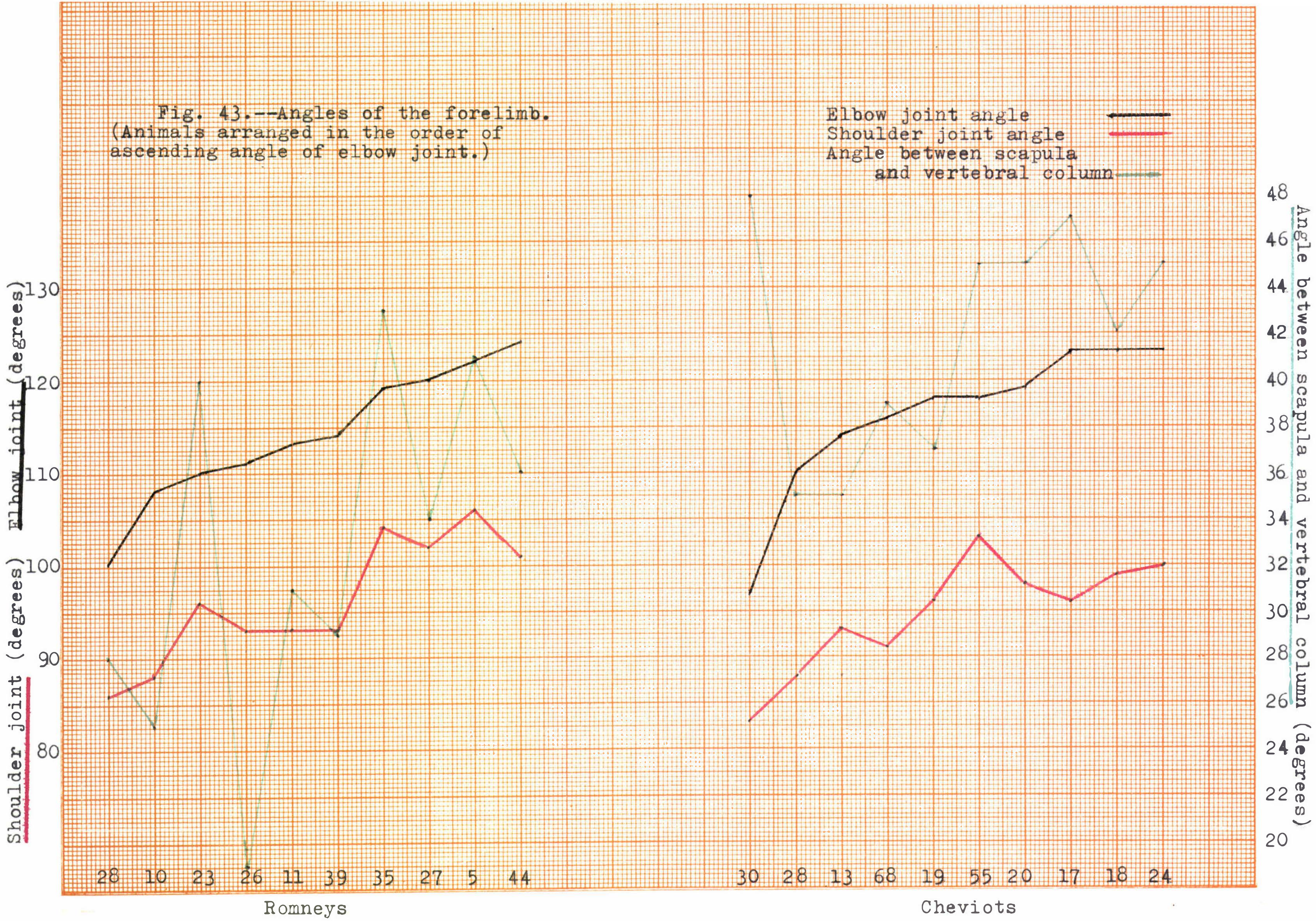


Fig. 43.--Angles of the forelimb.
(Animals arranged in the order of
ascending angle of elbow joint.)
Elbow joint angle
Shoulder joint angle
Angle between scapula
and vertebral column
Elbow joint (degrees)
Shoulder joint (degrees)
Angle between scapula and vertebral column (degrees)
130
120
110
100
90
80
48
46
44
42
40
38
36
34
32
30
28
26
24
22
20
28 10 23 26 11 39 35 27 5 44
30 28 13 68 19 55 20 17 18 24
Romneys
Cheviots

TABLE 120

CORRELATIONS BETWEEN
ANGLES BETWEEN THE LONG BONES IN THE SAME ANIMAL

The Correlation	Pairs	r (Romney)	r (Cheviot)
Elbow angle with shoulder angle	10	+0.906 **	+0.657 *
Elbow angle with angle between the scapula and vertebrae	10	+0.561 NS	+0.085 NS
Shoulder angle with angle between the scapula and vertebrae	10	+0.761 **	+0.185 NS

Correlation coefficient necessary for significance at the five per cent level is 0.602 and for the one per cent level of probability is 0.735.

It is shown in Table 120 that the elbow and the shoulder angles are correlated to a significant degree in both groups and the relationship between the shoulder angle and the angle between the scapula and the vertebrae in the Romney group is also significant.

I. Locomotion

The limbs of the quadruped are responsible for two functions. The first is the support of the mass of the organism and the second is concerned with locomotion. These two functions, in helping to shape the natural form of the individual limb and associated structures, interact and are dependent on one another. Hence, the components of the limb are neither strictly for support or for movement but for a combination of the two. This dual purpose has made studies of the physics of the limb very difficult indeed.

Two obvious facts facilitate the study of limb movement in the ungulate. They are, as Gray (1944) points out:- (1) when the animal is at rest the long axes of the limbs are in approximately a vertical plane and (2) the forces produced by the musculature which displace the limbs forward or backward are greater than those which tend to displace the limb laterally. Hence, a simplified version of the limb moving in an arc in one plane is justified. In this simple case the limb has two functions;- (1) that of being a longitudinal strut and (2) that of acting as a propulsive lever. In the forward movement of the entire organism, the ungulate's limbs achieve two things:- (1) the centre of gravity is shifted forward and (2) at the same time the equilibrium is maintained (Howell, 1944).

The limb itself can be likened to a series of levers that fold and unfold while fulfilling the locomotive function. One complicating circumstance in this notion is that each of the joints or links are closing or opening at a different rate at any given instant. To simplify the concept of a compound lever movement, Howell (1944) has divided the "stride of locomotion" (the completed action by a single limb) into four periods. For the pectoral limbs these are:- (1) when advanced, the limb first pulls the body forward, (2) when the foot passes the point directly below the shoulder, it pushes the body upward and forward, (3) at the end of the push, the leg is bent and pulled forward clear of the ground and (4) then pushed forward in extension ready to begin again the first period. In most animals, the second period is not important in the movement of the fore limb. This is because the centre of gravity of the usual quadruped is nearer the fore-end and too much emphasis on this period would throw the animal out of equilibrium. This action is better demonstrated in the propulsive thrust of the pelvic limbs. These facts have been excellently illustrated by Manter (1936) in an experiment using the cat as a representative quadruped.

To further simplify the above four periods in the action of the fore limb of the sheep they will be combined so that henceforth only two periods will be considered. The ground contact periods of pulling and pushing are combined and will be termed the "work phase" while the free moving periods of the distal part of the limb will be put together and called the "flight phase". This latter term has been used by Rashevsky (1946) to describe the period when the limb is detached from the ground. One group of muscles is more directly concerned with the movement of the limb during the "flight phase" of lifting the limb from the ground and throwing it forward.

Another group of muscles takes over at the end of the "flight phase" and exerts the power necessary to complete the "work phase".

It is realized that most muscles have more than one purpose, but certain of the muscles are more directly concerned with one of the above "phases" than with any other action or function. Hence, it is possible to form two muscle groups on the basis of the "phase" with which they are associated.

Those muscles most concerned with the lifting of the fore limb from the ground and swinging it forward are the biceps brachii, the brachiocephalicus, the supraspinatus and the brachialis. The trapezius and the rhomboideus also assist in this movement. The trapezius is a divided muscle and its posterior part assists in the opposite motion, so for purposes of clarity, it is omitted from both "phase" groups. The rhomboideus (a relatively small muscle in the sheep) is also left out because its function is mixed up with being a limb-trunk connector and in preventing lateral movement of the scapula. The flexors of the carpal and other more distal joints join in the "flight phase", but as none of the muscles of the fore-arm were dissected and weighed separately, they will have to be omitted.

In the "flight phase" the part played by the biceps brachii and the brachialis is to flex or close the elbow joint. This action causes the distal end of the radius-ulna to be moved further forward. The work performed by the supraspinatus in this "phase" is the extending or opening of the shoulder joint which adds to the reach of the fore-arm. The brachiocephalicus pulls the entire limb forward. Its action pulls the distal end of the scapula in an anterior direction and rotates the humerus in a clockwise direction to some extent.

Near the end of the "flight phase", the extensors of the joints of the lower part of the limb operate to straighten out the foot prior to its striking the ground. When the foot strikes the ground, (gravity, momentum and relaxation of the "flight phase" muscles acting) the "work phase" muscles come into operation to draw the body forward as it pivots on the hoof. A certain amount of braking action may take place here as gravity acting during the "flight phase" will tend to lower the body to some extent; hence part of the initial work of the "work phase" muscles will involve a slight "pole-vaulting" action. However, momentum will minimize the braking action and help carry the weight of the body slightly upward and forward past this braking factor.

During the "work phase" the following muscles appear to be the main ones responsible for carrying out the more direct pulls required for the completion of this "phase" :-

Triceps brachii	Teres major
Latissimus dorsi	Anconeus
Deep pectoral	Tensor fasciae antibrachii
Teres minor	The deltoids

The coraco-brachialis, the subscapularis and the infraspinatus may have some effect, but it is understood that they are more concerned with adduction and abduction of the arm and with acting as binders around the shoulder joint to help prevent dislocation. The triceps brachii, the deep pectoral and the latissimus dorsi, being the largest of the "work phase" group undoubtedly do most of the work of this "phase". The combined action of the "work phase" muscles results in a counter-clockwise movement of the scapula, the humerus and the radius-ulna as the body is carried forward. Needless to say, all the movements in both "phases" are highly coordinated, and it must be re-emphasized that the above description can be no more than a highly simplified version.

It would seem that the best animal (body and bone weights being equal) for climbing about in rough terrain would be the animal with the better developed "work phase" muscles. Hence, the next obvious step is to apply an analytical comparison to the data at hand. This is easily done by listing the weights of each animal's "flight phase" muscles as well as their "work phase" muscles. The "phase" totals for each animal can then be analysed by the analysis of variance technique as previously applied to the individual muscles.

The means and analyses of variance for the "phase" groups that are described above are shown in Tables 121 and 122.

TABLE 121

MEANS FOR
THE "PHASE" MUSCLE GROUPS

"Phase" group	Breed Type		Treatment		S.E.
	Romney	Cheviot	Fresh	Fixed	
"Flight phase"(gm)	327	326	305	348	11.9
"Work phase" (gm)	574	630	583	620	16.9

TABLE 122

ANALYSES OF VARIANCE
FOR "PHASE" MUSCLE GROUPS

Source	d.f.	SS	MS	F
For the "Flight Phase"				
Total	11	13377	-	
Between treatments	1	6504	6504	7.65 *
Between breeds	1	7	7	
Interaction	1	64	64	
Error	8	6802	850	
For the "Work Phase"				
Total	11	28408	-	
Between treatments	1	4219	4219	2.45
Between breeds	1	9241	9241	5.37 *
Interaction	1	1179	1179	
Error	8	13769	1721	

The means in Table 121 show the "flight phase" totals to be very much the same in both breed types, there being only one gram difference between the averages. However, the mean for the "work phase" group in the Cheviot breed type is much greater than in the Romney. The difference is significant as shown by the analysis of variance in Table 122.

The treatment means show the fixed group to be the heaviest in both cases. However, the difference is significant only in the "flight phase" group. As will be remembered from the analyses of variance for the brachiocephalicus (which is one of the largest muscles in this relatively small group), the same effect occurred for reasons previously given. It is possible that this one muscle affected the "flight phase" group enough to result in the treatment effect in the analysis of variance.

The angle of insertion of a muscle may affect locomotive abilities and muscular efficiency to a considerable degree.

Gregory (1912) from his studies on the horse and the mastodon and from a review of the work of Luciani (1906) shows that the more the angle of insertion of a muscle approaches a right angle, the more force can be exerted on that point and the greater will be the component of rotation (the pivot being, of course, the joint). When this angle becomes more acute, not all of the muscular force will be available for the movement of that part of the skeleton to which it is inserted. In most of the attachments of muscle to bone, it will be noted that the direction of the muscle fibres in relation to the direction of the shaft of the bone follow an oblique path. Thus, in similar organisms, the sizes of the muscles being the same, a difference in the angle of insertion will make one muscle more efficient and stronger for its size in performing a particular movement. This may affect a set of muscles and these may together make up an adaptation to some particular habitat even though the weights of the components may be the same in the animal not adapted to that habitat. However, in the wild ungulates which must depend on speed on relatively level country, the angles of insertion of muscles that are directly responsible for moving the limbs, need to be in the oblique direction. The more acute the angle the further can the insertion be moved with the same amount of muscle contraction. Gregory (1912) very ably illustrates this fact by means of a diagram similar to the one shown in

Figure 44. Hence, factors coming into the speed of the distal end of a long bone are:- (1) the point of insertion of the muscle in relation to the joint, (2) the smallness of the angle of insertion, (3) the direction of the muscle fibres in relation to the bone which they help to move, (4) the speed of contraction of the muscles involved and (5) the distance through which the muscle contracts.

In the breed types studied no difference with regard to the above factors could be determined.

Fig. 44.--Showing that with equal contraction how the angle of insertion affects the distance travelled by the insertion. The broken lines represent muscles, and the solid lines represent bone. Alpha is the angle of insertion and beta is the angle of insertion when contracted.

J. Cross-sections of the Carcasses

The results of the photography of the transverse sections of the six carcasses is presented in Figures 45, 46 and 47. As will be readily seen from an inspection of these photographs, no major difference between breed types is apparent. One point brought out, however, it that in all carcasses, the muscles of the shoulder do not become prominent until anterior to the sixth rib. The narrowest portion of the carcass is in the vicinity of the fifth and sixth ribs. Although it was found that the Romney group carried about twice as much fat in the shoulder region than did the Cheviot group, the photographs of the cross-sections of that region do not show this.

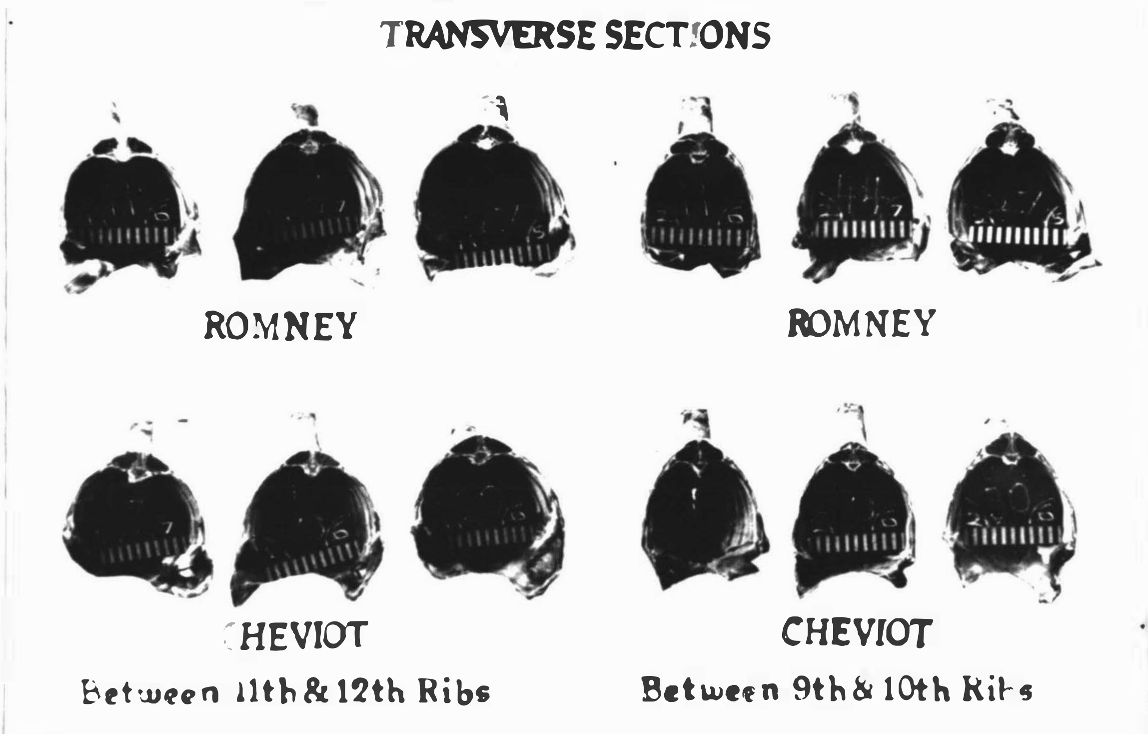


Fig. 45.--View of Transervse Sections of Carcasses

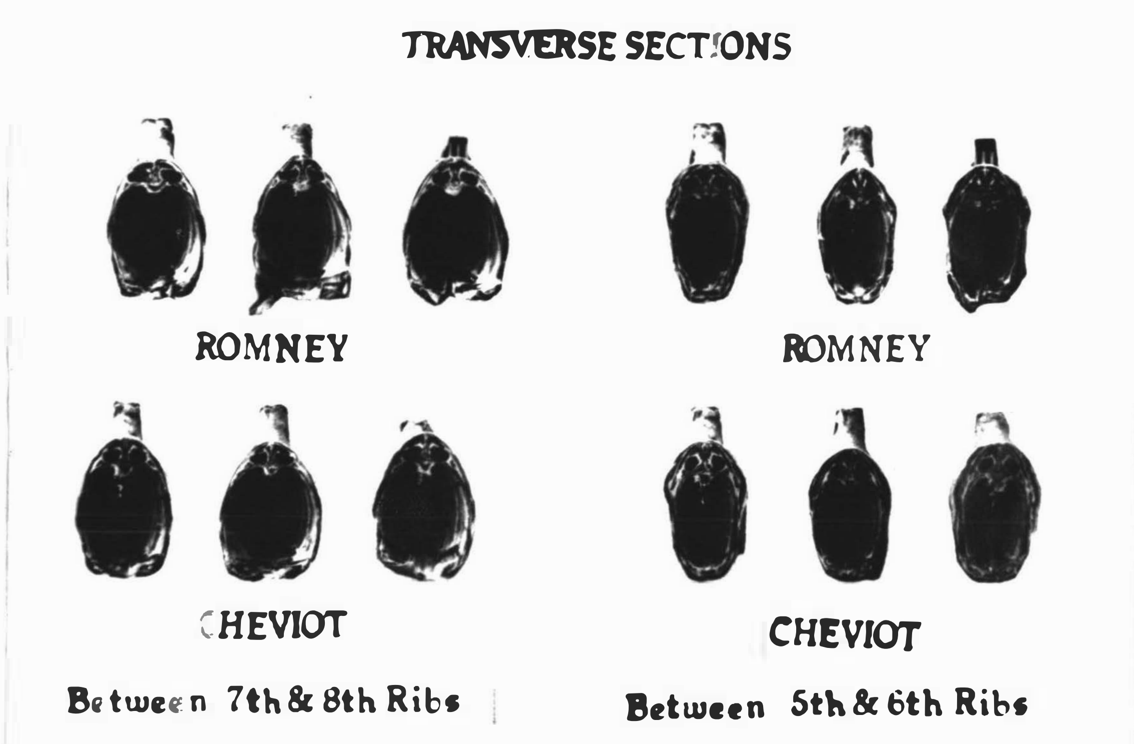


Fig. 46.--View of Transverse Sections of Carcasses

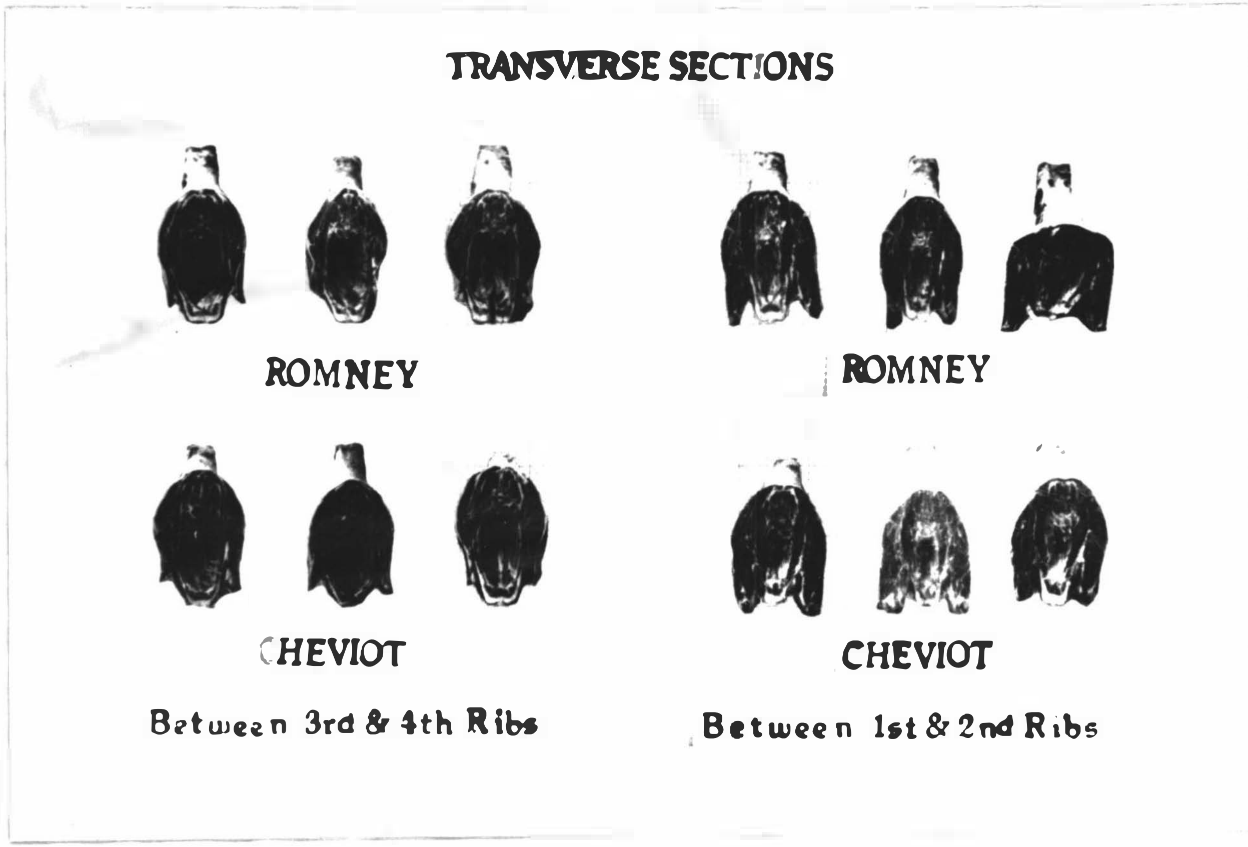


Fig. 47.--View of Transverse Sections of Carcasses

SECTION V

DISCUSSION AND SUMMARY

Three major factors served to make the comparison of the two contrasting breed types easier. The first of these was that the population from which the sample for study was drawn had been run in the same geographical environment since birth. Any factor that might have exerted an influence in shaping the animals' conformation was then common to both breed types. The second major factor in simplifying the type comparison was that all the animals studied were fully mature and that their history was fairly well known. As far as could be determined, none of the sheep studied had suffered from illness or malnutrition during their life. The third factor facilitating the type comparison was that there was no significant difference in body weight between the two groups. In other words they were nearly all the same size. Hence, in the treatment of the data, a direct comparison without special adjustment for varying size was made possible.

It was characteristic of the Romney sample that it showed greater variability in most characters studied. Although a careful attempt was made to secure Romneys typical of the breed, the necessity of getting both the Romneys and the Cheviot from an identical geographical environment limited the size of the population from which the sample was drawn. In the selection of the Romneys for the comparison with the Cheviot group there was certainly no conscious effort to select for variability. Thus, there is no apparent explanation for the greater variability within the Romney group.

The first apparent feature in the comparison of the Romney and Cheviot breed types was the difference in their temperament. Although, at first, the Cheviot group was the wilder, they proved to be more responsive to training. At the end of the training period, they were by far the easier group to handle, while the Romney group, although subjected to identical training, had not learned to lead and stand well.

In the series of live animal measurements used (heart girth, height at withers, depth of thorax and width between the lateral tuberosities of the humeri), all were found to be reliable if taken by either one observer or three observers. However, the last above-mentioned measurement was not as repeatable as the first three. The fact that the animals had a fleece of two to three inches in length made a difference only in the measurement of heart girth. Before shearing the heart girth measurement was about 1.2 inches greater than the same measurement after the animals had been shorn. However, even with the wool present, the measurement was very repeatable. The analyses of variance of the live animal measurements showed the Romney group to be significantly deeper in the thorax and larger in the heart girth, while there was no difference in height at withers and in width of shoulder.

Although measurements taken on the shoulder moulds revealed no breed type difference in area and base distance, the photographs of the moulds in Figure 17 do suggest a difference in shape between the groups. The sheep in the Romney group tend to have the same rounded shape irrespective of the size of the sheep while the Cheviots varied from a rather high, pointed shape to a rounded shape similar to that of the Romneys'. The fixing treatment had the effect of increasing the area of the mould to a significant extent.

Analyses of the series of carcass measurements showed a group difference on in two measurements. It was found that the Romney group had a greater leg measurement and the Cheviot group had a longer "eye muscle" measurement. Since the depth of the "eye muscle" is much the same in both groups, this latter difference tends to give the Cheviots the appearance of a more elliptical shape of "eye muscle" in the cross-section at the last rib. Although, as was shown by the results of the dissection, there was about twice as much fat in the shoulder region of the Romneys, this was not apparent in the fat measurements on the cross-section at the last rib. In addition to the above, a high correlation was found between the live animals and the carcasses for the measurements of thorax depth and shoulder width.

In the bone measurements, the variability within the Romney sample was very apparent. In spite of high standard deviations, a number of breed differences appeared. These were mainly in the thoracic vertebrae. It was discovered that the dorsal spines of the seven anterior thoracic vertebrae in the Cheviot group were significantly higher than those in the Romney sample. In both breed types the dorsal spines of the third thoracic vertebra was the highest and the second and fourth spines were nearly as high as the third. No difference between breeds was found in the angles that these spines make with the horizontal, but it was noted that the within breed variability was very high in both breed types for all thoracic spines. The analyses for the transverse thickness of the dorsal spines showed the Romneys to have the higher mean in all spines, the difference being significant for the 2nd, 3rd, 4th, 5th and 8th spines. The Cheviots had the wider dorsal, spines, the difference being significant for the first seven and for the twelfth spine. It was in the dorsal spines where the Romney group more closely fitted Hammond's (1932) description of a more improved mutton type as compared with the Cheviot group.

In the bones of the limb, the breed type differences were few. In the scapula, the position of the spine of the scapula appeared to vary between the breeds. In the Cheviot group the infraspinous fossa was wider while in the Romney group the supraspinous fossa was wider. There was no breed type difference in any of the measurements made on the cartilage of the scapula.

In the humerus the average measurements for the breed types were very much alike. It was found that on the humerus the circumference at mid-length is highly correlated with lateral with at the same point.

No breed type differences were found in the radius-ulna except in the antero-posterior width of the olecranon. In this measurement the Romneys were significantly greater. The average ratio of width to length was higher in the Cheviot group indicating a tendency for the radius-ulna to be proportionately narrower than in the Romneys.

In the metacarpus, the Romneys have significantly larger averages for circumference, lateral width and antero-posterior depth of this bone, while the Cheviot group had the greater mean length. As with the humerus, the circumference is highly correlated with the width of the humerus. However, only in the Cheviot group was the depth of the metacarpus correlated to a significant extent with the circumference. The average ratio of width to length is considerably higher in the Cheviots indicating a metacarpus of longer and narrower proportions, which according to Hammond (1932) is another indication of the level of improvement for mutton qualities.

There was no difference between the breed groups in any of the measurements on the ligamentum nuchae. However, it was found in comparing the length of the funicular part _in situ_ with its length after dissection, that the fixing technique resulted in considerable loss in tension as compared with the ligamentum nuchae from the fresh carcasses.

It was in the muscles that the differences between the treatments was most apparent. In the 115 comparisons, 36 significant treatment effects showed up. In 33 of these cases the measurements were larger on the fixed muscles. Most of the changes were in the measurements of length, width, depth and area. Only two of the significant treatment differences were in the weight comparisons. Some of the differences in linear measurements between the fresh and the fixed muscles were due to the distortion effects of hanging the carcasses over-night. It is not possible to say whether the treatment effect was due to a swelling of the fixed muscles or to a shrinking of the fresh muscles. Probably both factors have an effect. The estimation of volume of muscles by immersion, crude as it was, showed that the fixed muscles displaced about one per cent more water than did the fresh muscles. This supports the finding that most of the treatment effect was on the linear measurements and that weight of muscle was very little affected. The fixed muscles are, doubtless, nearer to the normal shape of the muscle in the living animal.

In the breed comparisons of muscles, the Cheviot group was significantly larger in 20 of the 115 comparisons while the Romney group was larger in two. The two cases where the Romney was the larger was in the length of the muscles concerned. Most of the measurements in which the Cheviots were significantly larger were those of weight of the muscle. All of the weight differences and many of the rest of the differences were in the muscles that flex the shoulder joint. Hence, in the Cheviots this greater mass of muscle concentrated around the shoulder joint could cause a bulge in that region and help to exaggerate the effect of sloping shoulders.

In the comparisons of bone, muscle and fat between the two breed types, it was found that the amount of muscle and bone in the region dissected was practically the same for both groups. The means for the breed groups showed that the Romneys were slightly heavier in the bones and that the Cheviots were slightly heavier in the muscles.

A regression of muscle on bone in the shoulder region showed that for every gram increase of bone there was a corresponding increase of about four grams in muscle. The numbers involved in the study were too small to enable a breed comparison to be attempted in this respect.

The Romneys had nearly twice as much fat in the shoulder region than did the Cheviots. In the analysis of variance for fat weights, no treatment effect was apparent. Expressing fat as a percentage of the total tissue dissected, the average Romney had approximately 28 per cent and the average Cheviot types had about 18 per cent.

The proportion of muscle to bone was larger in the Cheviot group and the percentage of fat to bone was higher in the Romney group. These facts, if interpreted according to Hammond (1932), indicate that the Romney is the more fully improved for mutton qualities.

The photographic studies of the cross-sections revealed no marked differences between the breed types, although on dissection it was demonstrated that the Romneys had more fat in the shoulder region. Because of the lack of major visible differences in the cross-sections, it is apparent, therefore, that the Cheviot type shoulder would not be discriminated against by the meat trade.

Except for one instance, the angulations measured from tracings of the X-ray plates showed no significant differences between breed types in regard to the normal articulate angles of the limb bones or between the limb bones and the horizontal plane. The one breed type difference was in the angle between the long axis of the radius-ulna and the horizontal. In this measurement the long axis of the radius-ulna was more vertical in the Cheviot group. This was significant at the five per cent level.

It was found that the angle between the posterior border of the scapula and the horizontal was about 50 degrees in these sheep and the angle between the long axis of the humerus and the horizontal was approximately 135 degrees. The angle between the long axis of the radius-ulna and the horizontal was about 70 degrees. The normal articulate angle between the scapula and the humerus was about 95 degrees in these sheep and the angle between the humerus and radius-ulna was approximately 115 degrees.

In the angle formed between the line of the thoracic part of the vertebral column and the horizontal, there was a significant breed type difference. This part of the vertebral column was more nearly parallel to the horizontal in the Cheviot group. Also, the angle between the posterior border of the scapula and the thoracic vertebrae was significantly less in the Romney group. These facts coupled with the presence of higher dorsal processes of the anterior thoracic vertebrae in the Cheviot group give the appearance of higher, sharper withers.

Correlations between the angle of the elbow joint and the angle of the shoulder joint were significant in both breed groups. In other words, when the elbow angle was larger in an animal, the shoulder angle was also larger. The correlation between the angle of the shoulder joint and the scapulo-vertebral angle was high in the Romney group and very low in the Cheviot group.

The muscles of the shoulder were grouped into two divisions for purposes of comparing the breed types on a basis of weight of the muscles concerned with verious phases of locomotion. In a very simplified version it was found that those muscles concerned with the "flight phase" of locomotion were very much the same in both breed types, while those concerned with the "work phase" (providing locomotive power) were significantly heavier in the Cheviot group. If weight is any criterion of muscular power, other things such as angles of insertion being equal, this means that the Cheviot group studied was more fit for active locomotion than was the Romney group.

Anatomically, the shoulder conformation difference between Cheviots and Romneys has been shown to be due mainly to the slope of the thoracic part of the vertebral column in combination with higher dorsal spines of the anterior thoracic vertebrae. The effect is further exaggerated by the Cheviots having larger muscles in the shoulder joint region and less fat in the region as a whole. The present study has not clarified the problem as to why the Cheviot should have this conformation. The solution to this awaits further research.

In our present state of knowledge it would be unwise for breeders to select against the typical shoulder conformation of the Cheviot. In the absence of contrary evidence, it can only be inferred that this shoulder conformation of the Cheviot is largely a result of a functional adaptation and would be better disregarded in selection.

Further information is required for the solution of the problems enunciated at the outset of this project. In particular, attention should be focussed on the functional adaptation of the Cheviots to hilly terrain. It is contended that

that locomotion studies linked with behavior investigations would enlighten the subject of anatomical form as related to adaptation.

Since quadrupedal locomotion is a highly co-ordinated process, it involves all parts of the organism. Therefore, the animal as a whole would require detailed investigation rather than one isolated region as was done in the present study.

The value of the present study would have been greater if pure breeds and larger numbers could have been available for detailed comparison.

Several of the techniques adopted were purely exploratory in nature, and in some instances greater refinement is possible. Although the X-ray technique was adequate for this study, later radiography showed that it could be further improved. It is believed, too, that the fixing technique, although very satisfactory in itself, could have been further improved if some method could be devised to embalm the animals in the standing position. Furthermore, the cross-sectioning technique would have been improved considerably if measurements both on the carcass sections and their photographs could have been perfected.

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APPENDIX I

Live Animal Measurements
Taken by One Observer

Height at withers before shearing

Sheep No.	1st Repeat (Inches)	2nd Repeat (Inches)	3rd Repeat (Inches)	4th Repeat (Inches)	5th Repeat (Inches)	6th Repeat (Inches)
			Romneys			
5	22.50	21.75	22.00	22.75	22.50	23.00
10	23.00	23.25	23.00	23.50	23.50	23.25
11	23.25	23.75	23.75	23.50	24.00	22.75
23	23.50	22.50	22.25	23.00	22.50	22.00
26	23.75	24.25	23.50	24.00	24.00	22.25
27	23.50	23.00	23.00	22.25	23.75	23.75
R28	21.75	21.50	22.75	21.50	22.50	22.00
35	22.25	22.00	23.00	21.50	23.75	22.50
39	23.25	22.50	23.00	21.50	22.25	22.25
44	22.00	22.00	22.00	21.75	22.50	22.25
Totals	228.75	226.50	228.25	225.25	231.25	226.00
Averages	22.88	22.65	22.83	22.53	23.13	22.60
			Cheviots			
13	22.25	24.00	22.50	23.00	23.00	22.00
17	21.50	21.25	21.00	22.75	22.00	21.75
18	23.00	23.50	21.25	22.50	22.75	23.50
19	22.00	22.25	22.25	23.50	21.00	22.25
20	22.50	21.50	23.00	22.75	21.25	23.25
24	23.00	23.25	23.50	24.00	23.25	23.50
C28	21.00	20.25	21.25	21.75	22.00	20.75
30	23.50	22.50	22.00	22.25	22.50	23.25
55	23.50	24.00	22.75	23.50	23.50	23.75
68	22.00	21.75	22.25	23.00	23.00	23.50
Totals	224.25	224.25	221.75	229.00	224.25	227.50
Averages	22.43	22.43	22.18	22.90	22.43	22.75

APPENDIX I (continued)

Height at withers after shearing

Sheep No.	1st Repeat (Inches)	2nd Repeat (Inches)	3rd Repeat (Inches)	4th Repeat (Inches)	5th Repeat (Inches)	6th Repeat (Inches)
			Romneys			
5	22.50	22.75	21.75	23.00	21.75	21.75
10	24.25	23.75	24.25	24.00	23.50	24.00
11	23.50	24.00	25.50	24.00	23.25	23.25
23	22.25	22.25	21.75	23.00	22.00	22.50
26	23.25	22.75	23.00	23.25	23.00	23.75
27	22.50	23.00	22.50	22.75	23.50	22.50
R28	21.50	21.50	21.25	22.50	21.25	21.00
35	22.75	22.50	22.25	22.25	22.50	22.25
39	23.00	23.50	23.50	23.50	21.50	22.75
44	22.75	22.00	22.25	22.50	22.00	21.75
Totals	228.25	228.00	228.00	230.75	224.25	225.50
Averages	22.83	22.80	22.80	23.08	22.43	22.55
			Cheviots			
13	24.00	23.50	23.00	22.75	24.50	23.75
17	22.25	21.75	21.50	21.50	21.75	23.00
18	23.25	23.25	21.75	24.00	24.00	24.00
19	23.00	22.50	22.50	22.75	23.50	23.50
20	22.00	22.75	22.25	22.00	23.25	23.50
24	23.25	23.50	23.50	22.25	23.50	23.75
C28	20.75	22.50	21.00	21.25	20.25	20.75
30	23.25	23.00	23.00	23.00	23.00	22.75
55	23.75	23.00	23.25	23.25	23.50	23.25
68	22.00	22.25	22.75	22.00	23.00	22.75
Totals	227.50	228.00	224.50	224.75	230.25	231.00
Averages	22.75	22.80	22.45	22.48	23.03	23.10

APPENDIX I (continued)

Heart girth before shearing

Sheep No.	1st Repeat (Inches)	2nd Repeat (Inches)	3rd Repeat (Inches)	4th Repeat (Inches)	5th Repeat (Inches)	6th Repeat (Inches)
			Romneys			
5	35.50	35.00	34.75	34.25	35.25	35.00
10	35.50	34.50	34.50	34.00	34.25	34.00
11	34.75	35.00	34.50	34.75	35.50	35.00
23	37.50	36.25	36.50	35.50	35.50	36.50
26	36.50	37.50	35.50	36.00	36.00	36.00
27	36.50	36.00	36.00	35.75	36.25	36.25
R28	35.50	35.00	34.50	34.75	34.50	33.75
35	33.75	33.00	33.50	33.25	34.00	33.25
39	37.25	36.75	37.75	37.50	37.50	36.75
44	34.50	34.75	33.50	34.25	34.75	35.50
Totals	357.25	353.75	351.00	350.00	353.50	352.00
Averages	35.73	35.38	35.10	35.00	35.35	35.20
			Cheviots			
13	35.25	35.00	35.00	36.00	35.00	35.50
17	33.00	33.75	33.25	33.00	33.50	33.00
18	34.50	35.00	35.00	34.50	34.50	34.50
19	35.50	35.00	34.50	34.50	34.75	34.50
20	32.75	33.25	33.00	33.00	33.75	33.50
24	34.00	34.00	34.00	34.00	34.25	33.50
C28	32.50	32.50	32.00	32.50	32.25	32.50
30	35.75	35.50	35.50	35.50	35.75	34.50
55	33.25	33.00	33.50	33.25	33.25	33.00
68	33.00	32.75	33.50	32.25	32.50	32.75
Totals	339.50	339.75	339.25	338.50	339.50	337.25
Averages	33.95	33.98	33.93	33.85	33.95	33.73

APPENDIX I (continued)

Heart girth after shearing

Sheep No.	1st Repeat (Inches)	2nd Repeat (Inches)	3rd Repeat (Inches)	4th Repeat (Inches)	5th Repeat (Inches)	6th Repeat (Inches)
			Romneys			
5	33.25	33.25	33.50	33.50	33.25	34.00
10	32.50	33.25	33.50	33.00	33.50	33.75
11	34.00	34.25	34.50	34.00	34.25	34.00
23	35.25	34.25	34.50	34.50	35.75	35.75
26	35.50	34.50	35.00	35.50	34.50	35.50
27	36.00	35.25	35.75	35.00	35.00	34.75
R28	33.75	33.75	33.25	33.75	33.50	35.00
35	32.75	31.75	32.50	32.50	32.50	33.50
39	36.50	36.00	36.25	36.75	36.25	37.25
44	33.50	33.25	33.00	33.00	33.50	34.25
Totals	343.00	339.50	341.75	341.50	342.00	347.75
Averages	34.30	33.95	34.18	34.15	34.20	34.78
			Cheviots			
13	33.50	33.25	34.25	33.75	33.50	34.25
17	32.00	32.00	32.00	32.00	31.50	33.25
18	33.25	33.00	33.50	33.50	33.75	33.75
19	34.00	33.00	33.50	33.25	33.50	34.00
20	31.50	32.00	31.25	31.50	31.00	31.75
24	32.50	32.00	32.00	32.00	32.50	33.25
C28	30.50	31.25	30.75	31.00	31.00	30.25
30	34.50	33.50	33.75	33.75	34.00	34.50
55	32.00	31.50	31.75	32.25	32.00	33.25
68	31.50	31.50	31.00	31.25	31.00	32.00
Totals	325.25	323.00	323.75	324.25	323.75	330.25
Averages	32.53	32.30	32.38	32.43	32.38	33.03

APPENDIX I (continued)

Depth of thorax before shearing (inches)

Sheep No.	1st Repeat	2nd Repeat	3rd Repeat	4th Repeat	5th Repeat	6th Repeat
			Romneys			
5	12.50	12.50	12.50	12.25	12.00	12.50
10	12.25	12.00	12.25	12.50	12.25	12.00
11	12.75	12.50	12.75	12.00	12.50	12.25
23	12.50	12.00	13.00	13.00	12.75	12.50
26	12.75	12.75	12.75	12.50	12.25	12.25
27	12.75	12.50	13.00	12.50	12.50	12.75
R28	12.25	12.25	12.75	12.25	12.25	12.00
35	12.00	12.00	12.00	11.50	11.75	12.00
39	12.75	13.00	12.50	12.50	12.25	13.00
44	12.50	12.50	12.75	12.75	12.50	12.25
Total	125.00	124.00	126.25	123.75	123.00	123.50
Average	12.50	12.40	12.63	12.38	12.30	12.35
			Cheviots			
13	13.00	12.50	12.50	13.00	13.00	12.75
17	12.25	12.25	12.25	12.00	12.00	12.00
18	12.25	12.00	12.25	12.50	12.25	12.50
19	12.00	12.25	12.00	12.25	12.00	12.25
20	11.75	12.00	11.50	12.00	11.50	11.75
24	12.25	12.25	12.25	12.50	12.00	12.25
C28	11.75	12.25	12.00	11.75	11.50	11.50
30	12.25	12.25	12.00	12.50	12.75	12.50
55	12.25	12.25	12.25	12.00	12.25	12.00
68	12.00	11.75	12.25	12.25	11.75	11.75
Total	121.75	121.75	121.25	122.75	121.00	121.25
Average	12.18	12.18	12.13	12.28	12.10	12.13

APPENDIX I (continued)

Depth of thorax after shearing (inches)

Sheep No.	1st Repeat	2nd Repeat	3rd Repeat	4th Repeat	5th Repeat	6th Repeat
			Romneys			
5	12.00	12.00	12.25	12.25	12.50	12.25
10	12.00	12.25	12.25	12.00	12.25	12.00
11	12.25	12.50	12.75	12.50	12.25	12.25
23	12.75	12.50	12.25	12.75	12.50	12.50
26	12.25	12.75	12.25	12.50	12.50	12.50
27	13.00	12.75	12.75	12.75	12.75	12.50
R28	12.00	12.25	12.25	12.25	12.25	12.25
35	11.75	11.75	11.75	12.00	11.75	12.00
39	12.25	12.25	12.25	12.50	12.25	12.25
44	12.25	12.50	12.75	12.50	12.50	12.50
Total	122.50	123.50	123.50	124.00	123.50	123.00
Average	12.25	12.35	12.35	12.40	12.35	12.30
			Cheviots			
13	12.25	12.50	12.50	12.50	12.50	12.50
17	12.00	12.00	11.75	12.00	11.75	12.00
18	12.00	11.75	12.00	12.00	12.50	12.25
19	12.25	11.75	12.00	12.50	12.00	12.50
20	11.75	11.50	11.75	12.00	11.50	12.00
24	12.00	12.50	12.25	12.25	12.00	12.25
C28	11.25	11.50	11.50	11.50	11.50	11.50
30	12.25	12.50	12.50	12.50	12.50	12.75
55	12.00	12.00	12.25	12.25	12.50	12.50
68	12.00	11.50	11.75	12.00	12.00	11.75
Total	119.75	119.50	120.25	121.50	120.75	122.00
Average	11.98	11.95	12.03	12.15	12.08	12.20

APPENDIX I (continued)

Width between lateral tuberosities of the humeri before shearing (inches)

Sheep No.	1st Repeat	2nd Repeat	3rd Repeat	4th Repeat	5th Repeat	6th Repeat
			Romneys			
5	9.00	8.75	8.50	8.75	8.75	8.75
10	9.50	9.00	9.00	8.25	8.50	8.50
11	8.50	8.50	8.50	8.50	8.25	8.50
23	9.75	8.75	9.50	9.50	9.00	9.00
26	9.25	9.00	9.50	8.75	9.00	9.00
27	9.25	8.50	8.75	8.50	8.75	8.50
R28	8.50	8.25	8.75	8.00	8.25	8.00
35	8.00	7.50	8.00	7.50	7.75	7.50
39	9.50	9.00	9.25	9.50	9.25	9.00
44	8.25	8.25	8.50	8.25	8.25	8.00
Total	89.50	85.50	88.25	85.50	85.75	84.75
Average	8.95	8.55	8.83	8.55	8.58	8.48
			Cheviots			
13	9.00	9.25	9.50	9.25	8.75	9.25
17	8.75	8.75	8.50	8.25	8.25	8.75
18	9.00	8.25	9.00	9.00	8.75	9.25
19	8.75	8.25	9.00	8.50	8.50	8.00
20	9.00	8.50	8.00	8.25	8.50	8.50
24	8.25	8.75	8.75	8.25	8.25	8.25
C28	8.50	8.75	8.75	8.50	8.25	8.00
30	8.75	9.25	8.75	8.50	9.00	8.75
55	8.00	7.75	8.00	8.25	8.25	8.25
68	8.50	8.75	8.50	8.50	8.50	8.50
Total	86.50	86.25	86.75	85.25	85.00	85.50
Average	8.65	8.63	8.68	8.53	8.50	8.55

APPENDIX I (continued)

Width between
lateral tuberosities of the humeri after shearing
(inches)

Sheep No.	1st Repeat	2nd Repeat	3rd Repeat	4th Repeat	5th Repeat	6th Repeat
			Romneys			
5	8.25	8.50	8.50	8.25	8.50	8.75
10	8.75	8.50	8.50	8.50	8.50	8.50
11	8.50	8.00	8.25	8.25	8.25	8.25
23	8.75	9.00	9.00	9.00	8.75	9.00
26	9.25	9.25	9.25	9.00	9.00	9.00
27	8.50	8.25	8.75	9.00	8.50	8.50
R28	8.00	8.00	8.25	8.00	8.25	8.00
35	8.00	7.75	8.00	8.00	7.75	8.00
39	9.00	9.50	9.50	9.25	9.50	9.25
44	7.75	8.25	8.25	8.25	8.00	8.25
Total	84.75	85.00	86.25	85.50	85.00	85.50
Average	8.48	8.50	8.63	8.55	8.50	8.55
			Cheviots			
13	8.75	9.25	8.75	9.00	8.50	9.00
17	8.25	8.25	8.50	8.50	8.25	8.50
18	8.50	8.50	8.25	8.00	8.25	8.00
19	8.50	8.25	8.25	8.25	8.50	8.25
20	8.25	8.25	8.25	8.00	7.75	8.25
24	7.75	8.00	8.00	8.00	8.25	8.25
~~C28~~	~~8.25~~	~~8.25~~	~~8.00~~	~~8.25~~	7.75	8.00
30	8.25	8.75	8.25	8.25	8.50	8.75
55	7.75	7.75	7.75	7.75	8.00	8.00
68	8.25	8.50	8.25	8.25	8.00	8.25
Total	82.50	83.75	82.25	82.25	81.75	83.25
Average	8.25	8.38	8.23	8.23	8.18	8.33

APPENDIX II

Live Animal Measurements Taken by Three Observers

Height at withers (inches)

Sheep No.	Observer A 1st Repeat	Observer A 2nd Repeat	Observer B 1st Repeat	Observer B 2nd Repeat	Observer C 1st Repeat	Observer C 2nd Repeat
			Romneys			
5	22.25	22.75	22.75	23.25	21.50	22.75
10	24.00	23.75	23.75	24.25	23.00	23.25
11	23.00	23.50	23.75	24.00	23.25	24.25
23	22.25	22.25	22.50	23.50	23.00	22.50
26	24.00	22.75	23.50	23.25	22.75	23.25
27	23.50	22.50	23.50	23.50	22.75	23.25
R28	21.50	20.75	22.25	22.00	21.50	21.00
35	22.00	22.50	22.00	22.00	21.75	22.50
39	22.25	21.50	22.00	23.25	22.50	22.50
44	21.75	22.00	22.50	21.25	21.25	22.00
Total	226.50	224.25	228.50	230.25	223.25	227.25
Average	22.65	22.43	22.85	23.03	22.33	22.73
			Cheviots			
13	24.25	24.25	24.25	25.00	24.75	24.25
17	23.75	22.75	22.25	22.75	23.25	21.75
18	23.50	23.25	23.50	23.75	23.75	23.75
19	24.00	23.50	22.75	23.75	23.50	22.75
20	23.25	22.75	22.50	22.50	22.50	22.75
24	24.50	23.75	23.50	23.75	23.75	24.25
C28	21.00	21.75	21.75	21.75	21.25	21.50
30	23.25	22.25	23.00	22.25	23.25	23.50
55	24.00	23.50	23.50	23.50	23.50	23.75
68	23.50	23.00	23.75	22.75	23.50	23.00
Total	235.00	230.75	230.75	231.75	233.00	231.25
Average	23.50	23.08	23.08	23.18	23.30	23.13

APPENDIX II (continued)

Heart girth (inches)

Sheep No.	Observer A 1st Repeat	Observer A 2nd Repeat	Observer B 1st Repeat	Observer B 2nd Repeat	Observer C 1st Repeat	Observer C 2nd Repeat
			Romneys			
5	33.50	34.50	34.00	34.00	34.00	34.75
10	33.50	33.50	33.50	34.50	33.00	35.00
11	34.75	35.00	34.75	34.75	34.50	35.75
23	35.25	35.50	35.25	36.00	35.25	36.50
26	36.00	35.75	35.50	35.50	34.50	36.00
27	36.00	36.50	35.50	36.50	36.00	37.00
R28	33.50	34.75	34.50	34.50	35.50	34.75
35	33.50	34.00	34.25	34.25	33.75	33.50
39	37.25	36.50	36.50	37.50	37.25	37.50
44	34.25	34.50	34.00	35.00	34.00	35.50
Total	347.50	350.50	347.75	352.50	347.75	356.25
Average	34.75	35.05	34.78	35.25	34.78	35.63
			Cheviots			
13	37.25	36.50	36.50	37.50	37.25	37.50
17	32.75	33.00	32.25	33.00	32.50	33.75
18	33.75	34.25	34.00	35.00	34.00	35.00
19	34.25	34.50	35.25	34.25	34.25	34.75
20	32.50	32.75	32.00	32.75	33.00	32.75
24	35.25	35.50	35.25	36.00	35.25	36.50
C28	32.00	32.50	31.00	32.00	31.50	31.50
30	34.50	35.25	34.50	35.00	35.00	35.50
55	32.75	33.00	33.50	34.50	33.00	35.00
68	32.25	32.25	32.00	32.25	32.00	32.00
Total	337.25	339.50	336.25	342.25	337.75	344.25
Average	33.73	33.95	33.63	34.23	33.78	34.43

APPENDIX II (continued)

Depth of thorax (inches)

Sheep No.	Observer A		Observer B		Observer C	
	1st Repeat	2nd Repeat	1st Repeat	2nd Repeat	1st Repeat	2nd Repeat
			Romneys			
5	12.50	12.50	12.25	12.25	12.75	12.50
10	12.75	12.25	12.00	12.25	12.50	12.50
11	12.50	12.50	12.50	12.50	12.50	12.50
23	12.50	12.75	12.25	12.25	12.25	12.50
26	12.75	12.75	12.50	12.75	12.75	12.50
27	13.00	12.75	12.75	12.75	13.00	13.00
R28	12.25	12.25	12.00	12.50	12.25	12.25
35	11.75	11.75	12.00	11.75	11.75	12.00
39	12.50	12.75	12.50	12.75	12.75	12.50
44	12.25	12.50	12.25	12.50	12.75	12.75
Total	124.75	124.75	123.00	124.25	125.25	125.00
Average	12.48	12.48	12.30	12.43	12.53	12.50
			Cheviots			
13	12.75	12.75	12.25	12.50	12.75	12.75
17	12.25	12.25	12.00	12.25	12.25	12.25
18	12.75	12.50	12.25	12.25	12.50	12.50
19	12.50	12.50	12.25	12.50	12.50	12.50
20	12.25	12.00	12.00	11.75	11.75	12.00
24	12.50	12.50	12.25	12.25	12.25	12.25
C28	11.50	11.50	11.50	11.50	11.50	11.00
30	12.50	12.50	12.50	12.25	12.75	12.75
55	12.25	12.25	12.00	12.25	12.25	12.25
68	11.75	12.00	11.75	11.75	12.00	11.75
Total	123.00	122.75	120.75	121.25	122.50	122.00
Average	12.30	12.28	12.08	12.13	12.25	12.20

APPENDIX II (continued)

Width between
lateral tuberosities of humerus (inches)

Sheep No.	Observer A		Observer B		Observer C	
	1st Repeat	2nd Repeat	1st Repeat	2nd Repeat	1st Repeat	2nd Repeat
			Romneys			
5	8.50	8.50	8.50	8.75	9.00	9.00
10	8.75	8.75	8.50	8.75	8.75	8.75
11	8.50	8.50	8.50	8.50	8.00	8.50
23	9.00	9.00	9.00	9.25	8.75	9.50
26	9.00	9.25	9.25	9.50	9.25	9.75
27	8.75	8.50	8.50	8.50	9.25	9.00
R28	8.00	8.25	8.00	8.75	8.25	8.75
35	8.00	7.75	8.00	8.00	8.00	8.00
39	9.25	9.25	9.50	9.25	9.50	10.00
44	8.25	8.25	8.00	8.50	8.25	8.75
Total	86.00	86.00	85.75	87.75	87.00	90.00
Average	8.60	8.60	8.58	8.78	8.70	9.00
			Cheviots			
13	8.75	8.50	8.50	9.00	9.25	9.50
17	8.25	8.50	8.25	8.50	8.50	8.25
18	8.25	8.25	8.25	8.50	8.50	9.25
19	8.00	8.25	8.75	8.50	8.75	8.75
20	8.25	8.25	8.50	8.75	8.50	8.00
24	8.00	8.25	8.25	8.50	8.50	8.75
C28	8.00	8.00	8.25	8.75	8.75	8.25
30	8.50	8.75	8.50	9.00	8.25	8.25
55	8.00	8.00	8.00	8.25	8.75	8.75
68	8.00	8.50	8.50	8.50	8.25	8.75
Total	82.00	83.25	83.75	86.25	86.00	86.50
Average	8.20	8.33	8.38	8.63	8.60	8.65

APPENDIX III

Measurements on the Cadavers (Inches)

Sheep No.	Height at Withers 1st Repeat	Height at Withers 2nd Repeat	Height at Withers 3rd Repeat	Heart Girth 1st Repeat	Heart Girth 2nd Repeat	Heart Girth 3rd Repeat
20	22.75	23.00	22.75	34.75	34.75	34.75
24	23.00	23.00	22.75	34.75	34.75	34.75
68	22.75	22.75	22.75	33.50	33.25	33.50
10	23.50	23.75	23.75	35.50	35.25	35.50
23	23.75	23.75	23.50	36.50	36.75	36.50
R28	22.50	22.75	22.75	35.50	35.50	35.50

Sheep No.	Depth of Thorax 1st Repeat	Depth of Thorax 2nd Repeat	Depth of Thorax 3rd Repeat	Between Tuberosities 1st Repeat	Between Tuberosities 2nd Repeat	Between Tuberosities 3rd Repeat
20	12.25	12.00	12.00	8.25	8.00	8.00
24	12.50	12.50	12.50	7.75	7.75	7.50
68	12.00	12.00	12.00	8.00	8.00	8.00
10	12.75	12.50	12.50	8.50	8.50	8.50
23	12.75	12.75	12.75	8.50	8.50	8.50
R28	12.50	12.50	12.75	8.00	8.25	8.00

Body Weights (Pounds)

Sheep No.	Before fixing	After fixing	
20	108.6	110.0	1.4
24	101.9	104.1	2.2
68	98.2	104.3	2.1
10	110.8	114.6	3.8
23	120.8	124.4	3.6
R28	105.1	109.8	4.7

APPENDIX IV

Angles Measured on X-ray Plates (Degrees)

Sheep No.	Angles Between Bones: Elbow Joint	Shoulder Joint	Between the Scapula and Vertebrae
		Romneys (live)	
R28	100	86	28
10	108	88	25
23	110	96	40
26	111	93	19
11	113	93	31
39	114	93	29
35	119	104	43
27	120	102	34
5	122	106	41
44	124	101	36
		Romneys (fixed)	
10	115	104	19
23	119	105	29
R28	123	108	31
		Romney (carcass)	
11	116	110	13
		Cheviots (live)	
30	97	83	48
C28	110	88	35
13	114	93	35
68	116	91	39
19	118	96	37
55	118	103	45
20	119	98	45
17	123	96	47
18	123	99	42
24	123	100	45
		Cheviots (fixed)	
20	106	92	31
24	111	92	24
68	117	95	31
		Cheviot (carcass)	
C28	109	95	11

APPENDIX IV (continued)

Sheep No.	Angle Between Long Axes of Bone and Horizontal (degrees) Scapula-Horizontal	Humerus-Horizontal	Vertebrae-Horizontal	Radius-ulna-Horizontal
	Romneys (live)			
11	47	135	17	68
44	49	129	14	73
23	57	141	17	71
35	50	127	7	66
5	59	134	20	77
R28	50	145	21	64
39	50	137	21	71
27	43	122	11	62
26	41	129	22	61
10	46	139	21	67
	Romneys (fixed)			
10	43	120	23	55
R28	50	122	20	65
23	44	119	15	58
	Romney (carcass)			
11	29	100	16	36
	Cheviots (live)			
C28	44	135	9	66
68	52	143	15	79
13	44	131	10	65
19	53	137	17	76
18	50	131	9	74
24	53	133	8	76
20	56	139	12	77
30	59	155	11	73
55	56	134	13	71
17	51	135	5	78
	Cheviots (fixed)			
68	45	131	14	68
24	46	135	21	66
20	42	130	12	56
	Cheviot (carcass)			
C28	28	112	18	41

APPENDIX V

Measurements
from the Shoulder Moulds

Sheep No.	Area of Shoulder Mould (sq. cm)	Distance Between Lateral Tuberosities of Radii (cm)
	Romneys (live)	
44	390	19.2
35	391	19.5
R28	403	22.5
5	429	20.1
10	430	21.0
23	481	23.8
27	490	21.7
11	494	21.4
26	508	22.1
39	542	25.6
	Romneys (fixed)	
R28	548	19.4
10	553	20.6
23	571	21.1
	Cheviots (live)	
C28	383	20.5
24	408	19.7
55	431	19.1
30	432	20.3
68	440	20.3
20	442	19.4
17	471	20.9
18	483	19.8
13	489	21.2
19	504	22.0
	Cheviots (fixed)	
24	501	19.5
68	522	19.6
20	510	21.3

APPENDIX VI

Slaughter Weights (Pounds)

Sheep No.	Live Weight (starved)	Bled Weight	Hot Carcass Weight	Cold Carcass Weight	Dressing percentage	Weight of Hind Qrs.	Weight of Fore Qrs.
			Romneys				
5	95.4	91.0	47.8	47.1	49.4%	21.6	25.6
11	108.2	102.8	54.9	53.8	49.7	25.1	28.6
26	112.9	107.2	63.1	62.0	54.9	29.4	32.6
27	111.8	106.0	54.8	53.8	48.1	24.9	28.9
35	87.4	82.7	42.5	41.6	47.6	19.0	22.5
44	89.6	84.5	40.9	39.9	44.5	17.8	22.1
			Cheviots				
17	99.5	94.5	50.2	49.1	49.3	23.0	26.1
18	99.2	95.2	49.6	48.6	49.0	22.7	26.0
19	100.3	94.0	48.6	47.9	47.8	21.9	25.9
C28	89.0	84.7	45.8	44.7	50.2	21.3	23.4
30	106.0	100.8	55.1	53.9	50.8	25.2	28.7
55	84.8	80.3	44.9	44.0	51.9	20.2	23.8

APPENDIX VII

External Carcass Measurements (cm)

Sheep No.	"F"	"G"	"WR"	"WF"	"WTh"	"Th1"	"Th2"	"T"	"R"	"K"	"L"	"H"	"P"
						Romneys							
5	28.2	27.8	25.1	19.3	17.3	29.2	30.1	19.1	18.7	66.5	64.5	34.0	36.8
11	30.0	28.4	26.2	19.7	18.6	30.2	30.3	21.0	19.7	67.0	66.0	33.5	39.0
26	29.3	28.9	28.2	20.5	19.9	30.5	31.2	21.7	19.9	72.5	70.5	37.0	38.3
27	28.5	28.5	28.2	20.0	18.3	31.9	31.4	20.4	19.6	70.0	68.0	34.5	38.1
35	28.6	26.3	25.6	18.2	17.9	29.3	28.9	19.6	18.6	65.0	63.5	32.5	36.5
44	28.1	27.3	26.5	17.8	16.9	30.5	30.1	19.7	18.7	62.5	66.0	33.5	35.3
						Cheviots							
17	26.9	28.6	27.3	20.8	18.3	30.3	29.9	20.0	19.2	62.5	64.5	33.0	36.5
18	26.5	27.8	26.8	20.3	18.8	29.7	29.9	20.3	19.6	66.5	65.5	33.5	36.2
19	27.1	28.4	29.3	20.0	19.2	31.3	30.6	19.7	18.7	65.5	64.5	32.0	36.4
C28	28.4	28.5	25.1	20.0	18.2	28.3	28.8	20.3	18.8	63.0	64.0	33.5	37.7
30	27.1	29.7	28.9	21.1	19.1	31.3	31.1	19.6	19.1	64.5	67.0	34.0	35.8
55	28.0	27.9	24.3	19.2	16.9	30.2	30.3	20.3	19.4	65.0	66.5	34.5	35.7

APPENDIX VIII

Internal Carcass Measurements (mm)

Sheep No.	"A"	"B"	"C"	"D"	"X"	"Y"	"J"
			Romneys				
5	55	28	3	3	18	3	5
11	59	34	2	2	17	2	5
26	63	34	6	6	18	3	8
27	60	33	4	3	16	3	10
35	49	27	4	3	14	1	5
44	58	28	1	1	17	1	4
			Cheviots				
17	64	33	2	2	20	1	7
18	65	30	3	1	18	3	7
19	63	30	2	1	17	1	5
C28	60	28	1	1	12	1	3
30	67	30	4	2	27	3	10
55	68	29	1	1	18	1	4

APPENDIX IX

Measurements on the Thoracic Vertebrae

Vertical heights of dorsal processes (mm)

Romney Group

Vertebra Number	Fresh Animals 5	26	35	Fixed Animals 10	23	R28
T.1	42	43	40	46	47	44
T.2	48	45	48	49	54	49
T.3	48	46	49	48	53	48
T.4	48	46	47	47	53	47
T.5	46	46	43	45	52	48
T.6	43	43	41	41	48	44
T.7	41	42	41	39	48	43
T.8	40	42	39	39	46	43
T.9	39	39	36	37	44	41
T.10	36	35	31	34	38	36
T.11	32	30	29	30	32	32
T.12	26	23	21	24	24	24
T.13	23	22	20	22	22	22

Cheviot Group

	Fresh Animals 18	19	55	Fixed Animals 20	24	68
T.1	53	60	58	48	51	53
T.2	54	61	58	55	56	58
T.3	56	62	58	58	57	59
T.4	56	60	57	57	57	58
T.5	53	56	51	51	53	54
T.6	49	53	48	50	48	48
T.7	49	49	45	48	46	45
T.8	45	45	41	46	43	44
T.9	42	40	38	43	39	40
T.10	35	32	32	36	34	38
T.11	29	26	28	28	31	30
T.12	25	24	25	27	23	25
T.13	24	24	24	24	22	24

APPENDIX IX (continued)

Angulation of dorsal processes (degrees)

Romney Group

Vertebra Number	Fresh Animals 5	26	35	Fixed Animals 10	23	R28
T.1	65	48	59	63	59	57
T.2	59	44	57	62	58	52
T.3	56	43	52	53	57	52
T.4	50	44	52	48	55	52
T.5	50	42	48	47	52	50
T.6	45	43	48	41	50	46
T.7	45	43	51	44	52	50
T.8	48	50	52	48	55	56
T.9	50	57	56	51	61	65
T.10	60	66	63	59	71	76
T.11	77	81	75	73	86	83
T.12	92	98	89	87	99	85
T.13	100	101	109	113	114	110

Cheviot Group

	Fresh Animals 18	19	55	Fixed Animals 20	24	68
T.1	57	63	65	76	56	61
T.2	52	56	61	70	52	61
T.3	54	53	55	63	50	57
T.4	52	51	51	59	47	54
T.5	50	48	47	54	43	52
T.6	47	48	46	53	43	47
T.7	51	48	49	54	45	44
T.8	54	51	53	59	44	49
T.9	59	54	58	65	50	56
T.10	72	66	77	72	58	66
T.11	83	75	93	89	76	84
T.12	98	98	103	102	97	89
T.13	114	105	118	112	113	106

APPENDIX IX (continued)

Transverse thickness of dorsal processes (cm)

Romney Group

Vertebra Number	Fresh Animals 5	26	35	Fixed Animals 10	23	R28
T.1	0.84	0.87	0.74	0.89	0.86	0.85
T.2	1.00	1.15	0.89	0.97	0.87	1.18
T.3	0.89	0.96	0.71	0.98	0.88	1.00
T.4	0.93	0.78	0.69	0.83	0.85	0.82
T.5	0.86	0.74	0.65	0.85	0.83	0.66
T.6	0.75	0.69	0.53	0.71	0.75	0.58
T.7	0.69	0.59	0.49	0.63	0.62	0.48
T.8	0.58	0.49	0.38	0.51	0.45	0.43
T.9	0.45	0.39	0.35	0.49	0.44	0.40
T.10	0.51	0.44	0.37	0.40	0.43	0.44
T.11	0.53	0.55	0.41	0.53	0.44	0.50
T.12	0.62	0.53	0.52	0.59	0.47	0.48
T.13	0.58	0.54	0.68	0.56	0.51	0.52

Cheviot Group

	Fresh Animals 18	19	55	Fixed Animals 20	24	68
T.1	0.81	0.78	0.87	0.73	0.68	0.93
T.2	0.95	0.92	0.89	0.79	0.82	0.82
T.3	0.75	0.78	0.64	0.88	0.63	0.74
T.4	0.64	0.64	0.63	0.77	0.53	0.68
T.5	0.64	0.65	0.62	0.76	0.51	0.68
T.6	0.58	0.63	0.59	0.67	0.48	0.64
T.7	0.50	0.53	0.54	0.55	0.44	0.58
T.8	0.47	0.43	0.46	0.38	0.39	0.47
T.9	0.48	0.45	0.43	0.35	0.38	0.41
T.10	0.49	0.43	0.38	0.39	0.46	0.41
T.11	0.49	0.49	0.47	0.33	0.46	0.40
T.12	0.55	0.62	0.39	0.38	0.51	0.53
T.13	0.55	0.55	0.49	0.38	0.54	0.51

APPENDIX IX (continued)

Posterior-anterior width
of dorsal processes (cm)

Romney Group

Vertebra Number	Fresh Animals 5	26	35	Fixed Animals 10	23	R28
T.1	1.43	1.23	1.22	1.49	1.49	1.29
T.2	1.36	1.35	1.30	1.43	1.34	1.34
T.3	1.30	1.32	1.29	1.36	1.55	1.35
T.4	1.31	1.28	1.36	1.28	1.49	1.35
T.5	1.36	1.28	1.32	1.25	1.37	1.35
T.6	1.34	1.28	1.19	1.22	1.32	1.37
T.7	1.34	1.23	1.26	1.19	1.38	1.34
T.8	1.32	1.30	1.23	1.25	1.34	1.27
T.9	1.42	1.44	1.47	1.38	1.44	1.48
T.10	1.63	1.53	1.30	1.41	1.43	1.34
T.11	1.47	1.53	1.29	1.32	1.36	1.28
T.12	1.61	1.60	1.65	1.78	1.67	1.58
T.13	2.32	2.16	2.17	2.03	2.09	2.05

Cheviot Group

	Fresh Animals 18	19	55	Fixed Animals 20	24	68
T.1	1.67	1.55	1.81	1.76	1.58	1.87
T.2	1.52	1.52	1.60	1.63	1.45	1.80
T.3	1.47	1.49	1.57	1.58	1.54	1.62
T.4	1.48	1.42	1.54	1.70	1.49	1.54
T.5	1.62	1.41	1.58	1.58	1.49	1.57
T.6	1.46	1.34	1.48	1.45	1.38	1.49
T.7	1.41	1.38	1.35	1.30	1.41	1.41
T.8	1.34	1.23	1.50	1.27	1.32	1.52
T.9	1.49	1.28	1.64	1.49	1.34	1.56
T.10	1.41	1.26	1.23	1.62	1.23	1.33
T.11	1.34	1.42	1.46	1.46	1.27	1.48
T.12	1.65	2.00	2.11	1.98	1.86	1.94
T.13	2.23	2.23	2.47	2.23	2.10	2.38

APPENDIX X

Bone Measurements
(cm)

<u>Romney Group</u>

Measurement	Fresh Animals 5	26	35	Fixed Animals 10	23	R28
Scapula						
"ScA"	13.9	14.5	14.4	15.2	14.9	14.7
"ScB"	11.6	12.5	11.0	12.1	11.4	11.7
"ScC"	9.2	9.6	8.8	9.6	8.8	9.1
"ScD"	2.5	3.0	2.3	2.7	2.5	2.8
"ScE"	12.9	13.5	13.5	14.3	13.8	13.9
"SCF"	13.2	14.0	14.2	14.3	14.1	14.0
"ScG"	2.44	2.58	2.14	2.30	2.46	2.18
"ScB"/"ScD"	4.64	4.17	4.78	4.48	4.56	4.18
"ScC"/"ScD"	3.68	3.20	3.83	3.56	3.52	3.75
"ScE"/"ScB"	1.11	1.08	1.23	1.18	1.21	1.19
Humerus						
"HA"	14.1	14.6	13.8	14.8	14.8	13.9
"HB"	7.8	7.7	6.9	7.6	7.4	7.3
"HC"	2.24	2.23	1.83	2.14	2.15	2.00
"HD"	2.27	2.35	2.07	2.35	2.26	2.05
"HA"/"HB"	1.81	1.90	2.00	1.95	2.00	1.90
"HA"/"HC"	6.29	6.55	7.54	6.92	6.88	6.95
"HD"/"HC"	1.01	1.05	1.13	1.10	1.05	1.03
Radius-ulna						
"RA"	17.9	19.1	17.8	17.8	19.5	17.3
"RB"	2.39	2.40	1.98	2.26	2.21	2.00
"RC"	1.13	1.12	0.95	1.08	0.99	0.96
"RD"	2.72	2.54	2.44	2.65	2.57	2.48
"RA"/"RB"	7.49	7.96	8.99	7.88	8.82	8.65
Thoracic Vertebrae						
"ThVA"	29.5	31.6	29.3	34.8	30.5	28.9
"HA"+"RA"+"MA"	42.7	45.9	42.0	45.3	45.5	42.2
"RA" + "MA"	28.6	31.3	28.2	30.5	30.7	28.3
"MA"/"HA"	0.76	0.84	0.75	0.86	0.76	0.79
"RA"/"HA"	1.27	1.31	1.29	1.20	1.32	1.24

APPENDIX X (continued)

Cheviot group

Measurements	Frash Animals			Fixed Animals		
	18	19	55	20	24	68
Scapula						
"ScA"	14.3	15.1	15.0	14.1	15.3	14.6
"ScB"	11.9	12.1	11.9	11.4	11.8	12.4
"ScC"	9.7	9.9	9.5	9.2	9.7	10.3
"ScD"	2.6	2.4	2.6	2.4	2.3	2.4
"ScE"	13.6	14.2	14.2	13.3	14.4	13.9
"ScF"	13.8	14.1	13.8	13.4	14.4	13.8
"ScG"	2.23	2.25	2.29	2.49	2.23	2.37
"ScB"/"ScD"	4.58	5.04	4.58	4.75	5.13	5.17
"ScC"/"ScD"	3.73	4.13	3.65	3.83	4.22	4.29
"ScE"/"ScB"	1.14	1.17	1.19	1.17	1.22	1.12
Humerus						
"HA"	14.2	14.0	14.1	14.4	14.0	14.1
"HB"	6.8	7.0	6.8	7.6	6.8	7.3
"HC"	1.83	1.95	1.88	2.19	1.84	2.02
"HD"	2.00	2.13	2.14	2.32	2.19	2.30
"HA"/"HB"	2.09	2.00	2.07	1.89	2.06	1.93
"HA"/"HC"	7.76	7.18	7.50	6.58	7.61	6.98
"HD"/"HC"	1.09	1.09	1.14	1.06	1.19	1.14
Radius-ulna						
"RA"	18.9	18.1	18.8	19.2	18.6	18.4
"RB"	2.08	1.94	2.04	2.37	2.00	2.14
"RC"	1.00	1.03	0.98	1.06	1.02	1.01
"RD"	2.47	2.43	2.46	2.50	2.25	2.45
"RA"/"RB"	9.09	9.33	9.22	8.10	9.30	8.60
Thoracic Vertebrae						
"ThVA"	30.9	30.0	30.4	30.1	30.7	30.9
"HA"+"RA"+"MA"	45.0	43.6	44.8	45.0	44.7	44.1
"RA" + "MA"	30.8	29.6	30.7	30.6	30.7	30.0
"MA"/"HA"	0.84	0.82	0.84	0.79	0.86	0.82
"RA"/"HA"	1.33	1.29	1.33	1.33	1.33	1,30

Measurements on the metacarpus

Romneys

Measurement	11	27	44	5	26	35	10	23	R28
"MA"	11.3	10.9	10.3	10.7	12.2	10.4	12.7	11.2	11.0
"MB"	5.2	5.6	5.3	5.8	5.6	5.0	5.4	5.3	5.1
"MC"	1.84	1.88	1.87	2.09	1.99	1.76	1.87	1.88	1.85
"MD"	1.17	1.26	1.19	1.27	1.28	1.18	1.26	1.21	1.14
"MC"/"MD"	1.57	1.49	1.57	1.65	1.55	1.49	1.48	1.55	1.62
"MA"/"MC"	6.14	5.80	5.51	5.12	6.13	5.91	6.79	5.96	5.95
"MA"/"MB"	2.17	1.95	1.94	1.84	2.18	2.08	2.35	2.11	2.16
"MA"/"MD"	9.66	8.65	8.66	8.43	9.53	8.81	10.08	9.26	9.65

Cheviots

	17	C28	30	18	19	55	20	24	68
"MA"	11.6	11.2	11.9	11.9	11.5	11.9	11.4	12.1	11.6
"MB"	4.9	5.0	5.2	5.0	4.9	4.8	5.3	4.8	4.9
"MC"	1.68	1.71	1.80	1.69	1.66	1.64	1.85	1.58	1.69
"MD"	1.19	1.19	1.23	1.18	1.19	1.14	1.18	1.14	1.15
"MC"/"MD"	1.41	1.44	1.46	1.43	1.39	1.44	1.57	1.39	1.47
"MA"/"MC"	6.90	6.55	6.61	7.04	6.93	7.26	6.16	7.66	6.86
"MA"/"MB"	2.37	2.24	2.29	2.38	2.35	2.48	2.15	2.52	2.37
"MA"/"MD"	9.75	9.41	9.67	10.08	9.66	10.44	9.66	10.61	10.09

APPENDIX X (continued)

Weights of bones
(gm)

Romneys

Item	5	26	35	23	10	R28	11	27	44
Scapula	87.1	98.5	64.6	86.4	83.0	73.8			
Cartilage of scapula	18.6	18.6	14.6	22.0	16.6	15.0			
Humerus	112.6	124.4	92.8	115.3	123.9	90.8			
Radius-ulna	87.5	98.1	69.2	80.3	85.3	68.7			
Metacarpus	40.9	45.3	34.1	38.6	45.9	35.0	39.7	39.8	34.4

Cheviots

Item	18	19	55	20	24	68	17	C28	30
Scapula	78.0	78.1	71.5	85.5	76.9	81.1			
Cartilage of scapula	16.4	14.6	18.2	19.1	18.8	17.7			
Humerus	100.7	104.2	98.3	122.4	97.9	103.2			
Radius-ulna	78.6	80.9	72.9	91.0	70.1	75.5			
Metacarpus	37.3	37.7	36.3	40.2	37.1	38.5	36.5	38.4	39.5

APPENDIX XI

Measurements on the Ligamentum Nuchea (cm)

Romney Group

Measurement	Fresh Animals 5	26	35	Fixed Animals 10	23	R28
Length (*in situ*)	43.5	47.8	43.8	44.4	43.7	42.8
Length (dissected)	32.5	26.3	33.6	39.2	37.4	38.0
Weight (gm)	26.8	33.9	25.8	37.1	33.8	29.7
Width (one strand)	0.9	1.1	0.9	0.9	0.9	0.9
Width (two strands)	2.0	2.4	2.0	2.1	1.9	1.9
Depth	0.5	0.7	0.7	0.7	0.8	0.9

Cheviot Group

	Fresh Animals 18	19	55	Fixed Animals 20	24	68
Length (*in situ*)	43.8	44.0	44.3	43.7	43.9	43.6
Length (dissected)	34.5	31.5	34.5	36.4	36.2	38.0
Weight (gm)	29.2	25.6	29.9	33.0	29.7	34.7
Width (one strand)	1.1	0.9	1.0	1.1	0.9	1.0
Width (two strands)	2.3	2.0	2.1	2.2	2.0	2.1
Depth	0.6	0.5	0.8	0.7	0.7	1.0

APPENDIX XII

Muscle Weight (gm)

Romney group

Muscle	Fresh Animals 5	26	35	Fixed Animals 23	10	R28
Latissimus dorsi	92.1	107.8	75.0	108.1	113.6	94.9
Deltoideus pars acromialis	14.1	16.3	10.0	13.4	17.0	13.7
Deltoideus pars scapularis	13.4	11.4	7.8	11.3	13.7	12.0
Infraspinatus	141.7	178.3	119.9	187.0	194.0	156.1
Teres minor	9.8	14.1	10.6	12.5	12.2	10.1
Supraspinatus	131.4	159.6	120.3	165.8	187.8	153.4
Teres major	26.5	34.2	22.5	31.1	36.2	30.2
Subscapularis	84.9	80.8	63.4	79.5	80.5	73.2
Tensor fascia antibrachii	14.3	17.5	14.8	19.2	14.5	21.1
Triceps (lateral head)	43.3	49.4	46.4	47.7	50.5	49.0
Triceps (long head)	136.4	164.5	121.7	145.1	148.6	158.7
Triceps (medial head)	14.5	15.3	10.5	14.0	14.5	10.5
Biceps brachii	34.2	42.2	30.9	40.1	39.7	30.7
Coraco-brachialis	9.8	10.8	5.9	10.4	11.4	7.8
Brachialis	23.7	28.9	18.5	26.3	28.5	22.6
Anconeus	10.1	8.6	7.8	10.9	12.2	9.4
Trapezius	53.9	59.1	39.0	63.6	66.0	60.5
Brachiocephalicus + omo-tr.	103.3	112.8	83.8	135.6	130.0	114.1
Superficial pectoral	46.2	64.0	42.8	70.0	62.1	57.7
Sterno-scapularis	22.5	23.1	13.8	21.4	25.0	22.0
Deep pectoral	168.4	187.4	138.4	182.1	182.2	187.1
Rhomboideus	53.8	68.4	47.8	56.5	58.7	52.6
Serratus thoracis	264.8	354.8	225.3	330.5	301.3	291.3
Muscles of the fore arm	166.1	185.5	144.6	172.7	191.3	160.2

APPENDIX XII (continued)

Cheviot group

Muscle	Fresh Animals 18	19	55	Fixed Animals 20	24	68
Latissimus dorsi	110.8	119.8	105.3	95.1	101.3	119.2
Deltoideus pars acromialis	17.6	20.1	18.8	18.4	18.8	16.8
Deltoideus pars scapularis	13.4	15.8	15.0	15.2	11.8	14.0
Infraspinatus	168.8	177.3	183.9	180.1	184.1	191.3
Teres minor	11.5	11.5	13.2	13.6	13.6	12.1
Supraspinatus	152.6	151.4	141.4	169.2	153.1	152.4
Teres major	38.2	33.7	38.1	33.1	39.3	41.7
Subscapularis	75.2	73.0	74.7	79.9	83.5	76.2
Tenson fascia antibrachii	15.4	15.7	15.9	16.4	20.9	16.4
Biceps brachii	34.9	41.0	37.3	40.2	38.8	34.0
Coraco-brachialis	11.5	11.3	10.2	10.5	10.9	10.1
Brachialis	21.8	28.5	24.9	24.5	21.7	25.6
Anconeus	13.2	13.4	13.5	16.9	12.3	10.4
Triceps (medial head)	15.5	18.6	16.1	23.4	15.0	15.4
Triceps (lateral head)	53.4	46.2	59.1	64.0	54.8	55.1
Triceps (long head)	161.8	147.7	162.8	173.2	154.9	160.3
Trapezius	52.6	87.5	56.2	53.6	58.3	68.7
Brachiocephalicus + omo-tr.	107.0	92.8	106.5	110.5	110.2	130.5
Superficial pectoral	53.0	58.0	55.5	76.7	54.8	59.7
Sterno-scapularis	19.1	19.2	17.9	21.3	19.0	18.6
Deep pectoral	182.1	175.0	152.8	180.2	177.6	182.3
Rhomboideus	51.1	49.5	51.7	55.6	48.1	55.5
Serratus thoracis	251.5	285.1	293.8	295.5	252.8	300.1
Muscles of the fore arm	158.2	164.3	168.1	191.6	160.0	150.6

APPENDIX XIII

Muscle Length (cm)

Romney group

Muscle	Fresh Animals			Fixed Animals		
	35	26	5	23	10	R28
Latissimus dorsi	22.6	24.4	25.5	27.2	25.1	25.0
Deltoideus pars acromialis	7.6	8.0	8.1	8.6	10.1	8.5
Deltoideus pars scapularis	6.1	6.6	7.0	8.2	9.8	7.8
Infraspinatus	17.2	17.6	14.9	19.1	18.7	18.3
Teres minor	8.5	8.2	8.2	8.5	9.1	8.6
Supraspinatus	16.1	16.7	16.2	17.4	17.1	16.5
Teres major	14.2	14.1	13.6	16.0	15.4	15.2
Subscapularis	18.0	18.0	16.9	18.1	17.8	17.5
Tensor fascia antibrachii	13.4	14.6	14.3	15.6	15.7	14.8
Triceps (lateral head)	9.8	11.1	10.0	10.3	10.6	9.5
Triceps (long head)	14.3	13.9	14.5	15.4	16.2	15.3
Triceps (medial head)	7.5	10.0	9.1	9.7	8.9	7.7
Briceps brachii	9.1	9.5	9.6	11.3	10.6	9.6
Coraco-brachialis	7.9	10.1	10.1	10.5	9.2	7.6
Brachialis	10.4	11.3	10.8	11.4	11.6	10.4
Anconeus	6.1	6.1	6.7	7.2	7.0	6.4
Trapezius	29.5	33.6	31.6	29.8	30.2	26.0
Brachiocephalicus + omo-tr.	26.7	28.6	27.5	38.9	35.8	37.1
Superficial pectoral	19.3	18.6	16.9	19.6	21.1	19.9
Sterno-scapularis	9.2	9.4	9.0	8.0	8.7	8.6
Deep pectoral	32.7	33.8	33.2	34.7	33.0	31.2
Rhomboideus	23.8	27.7	22.9	21.2	22.4	19.0
Serratus thoracis	26.1	29.7	28.2	26.1	25.6	26.0
Cartilage of scapula (anterior-posterior)	14.1	14.9	14.6	17.0	16.4	15.1

Cheviot group

Muscle	Fresh Animals 18	19	55	Fixed Animals 20	24	68
Latissimus dorsi	26.2	26.2	26.2	26.2	23.3	24.0
Deltoideus pars acromialis	8.4	8.0	8.0	10.1	9.2	8.9
Deltoideus pars scapularis	7.1	7.2	8.0	8.0	8.0	8.5
Infranspinatus	17.7	17.4	18.0	18.9	19.1	19.4
Teres minor	7.8	7.9	7.8	9.5	8.5	8.6
Supraspinatus	16.4	16.7	16.8	15.9	18.3	16.9
Teres major	14.0	14.8	14.5	13.9	15.2	15.3
Subscapularis	17.6	17.4	18.1	16.4	18.1	18.0
Tensor fascia antibrachii	13.2	14.9	14.7	17.3	14.1	13.0
Triceps (lateral head)	10.7	11.0	10.7	11.2	11.5	11.2
Triceps (long head)	12.5	14.2	13.2	14.1	14.4	15.0
Triceps (medial head)	9.3	9.9	9.2	9.7	9.8	9.6
Biceps	9.5	9.7	9.0	10.1	10.2	11.3
Coraco-brachialis	9.0	8.5	8.2	8.8	7.9	8.1
Brachialis	10.7	11.4	11.2	11.7	10.5	10.7
Anconeus	6.7	7.6	7.0	7.2	7.2	6.5
Trapezius	31.8	33.2	32.6	26.2	30.0	27.7
Brachiocephalicus + omo-tr.	29.4	28.8	29.9	35.9	37.1	38.1
Superficial pectoral	17.2	19.4	18.9	18.6	20.4	18.9
Sterno-scapularis	9.0	8.1	8.9	7.9	8.0	8.2
Deep pectoral	34.9	36.4	34.0	31.8	36.0	32.5
Rhomboideus	21.2	19.9	25.0	18.9	20.8	21.6
Serratus thoracis	22.3	24.5	24.7	24.5	23.8	23.7
Cartilage of the scapula (anterior-posterior)	14.6	15.2	14.9	15.7	15.1	15.3

APPENDIX XIV

Muscle Width (cm)

Romney group

Muscle	Fresh Animals 35	26	5	Fixed Animals 23	10	R28
Latissimus dorsi	16.0	15.1	15.7	17.4	18.2	16.5
Deltoideus pars acromialis	3.7	3.4	3.3	3.7	4.0	3.4
Deltoideus pars scapularis	2.7	3.6	2.8	3.4	3.2	2.9
Infraspinatus	7.2	8.5	8.6	9.6	8.1	8.7
Teres minor	2.5	3.0	2.5	2.5	2.9	2.7
Supraspinatus	6.1	6.7	6.6	6.7	6.8	6.0
Teres major	2.9	3.7	3.2	3.5	3.6	3.4
Subscapularis	8.5	9.1	8.6	8.7	8.5	8.1
Tensor fascia antebrachii	2.4	2.0	2.3	2.6	2.1	2.5
Triceps (lateral head)	4.5	4.6	5.0	5.2	5.6	4.8
Triceps (long head)	7.5	8.7	8.0	8.4	7.9	7.2
Triceps (medial head)	3.0	4.0	4.3	3.1	3.8	3.8
Biceps brachii	2.8	3.5	3.1	3.1	2.9	2.8
Coraco-brachialis	3.1	2.8	3.3	4.0	3.6	3.3
Brachialis	4.0	4.1	4.1	4.0	3.8	3.8
Anconeus	2.3	2.0	2.4	2.5	2.6	2.4
Trapezius	9.4	11.3	8.4	15.9	15.0	14.4
Brachiocephalicus +omo-tr.	7.6	8.5	7.3	9.1	10.1	8.1
Superficial pectoral	12.0	11.6	11.6	9.9	10.0	9.7
Sterno-scapularis	4.6	5.4	5.3	6.2	6.4	5.9
Deep pectoral	10.6	11.7	12.9	12.8	13.0	10.9
Rhomboideus	8.5	10.0	8.1	8.5	9.2	9.6
Serratus thoracis	18.2	19.7	17.8	21.5	21.4	18.7
Cartilage of the scapula (dorsal-ventral distance)	5.1	5.8	5.5	5.1	5.9	5.7

APPENDIX XIV (continued)

Cheviot group

Muscle	Fresh Animals 18	19	55	Fixed Animals 20	24	68
Latissimus dorsi	16.3	14.6	14.8	17.6	16.6	18.5
Deltoideus pars acromialis	4.3	4.2	4.2	3.9	3.9	3.7
Deltoideus pars scapularis	3.6	2.4	3.4	3.7	3.3	3.5
Infraspinatus	8.2	8.8	8.1	8.3	8.7	10.0
Teres minor	2.7	2.8	3.3	2.9	3.1	2.9
Supraspinatus	6.9	6.7	6.1	6.9	6.0	5.9
Teres major	4.0	3.8	4.2	3.8	4.1	4.5
Subscapularis	9.6	7.6	9.3	8.7	8.8	9.3
Tensor fascia antibrachii	2.5	2.2	2.2	2.5	2.6	2.2
Triceps (lateral head)	4.4	4.4	5.6	5.8	4.6	5.2
Triceps (long head)	9.1	9.4	8.4	8.7	9.0	8.6
Triceps (medial head)	3.8	4.2	4.1	4.7	3.8	4.1
Biceps	3.1	3.2	3.3	3.1	3.0	2.9
Coraco-brachialis	3.5	3.3	2.9	3.1	3.6	3.3
Brachialis	3.9	4.2	4.2	4.4	3.8	4.3
Anconeus	2.6	2.7	2.7	2.8	2.6	2.3
Trapezius	10.5	14.1	10.2	15.2	13.8	17.7
Brachiocephalicus + omo-tr.	7.5	7.3	6.6	9.1	8.0	8.0
Superficial pectoral	10.1	10.4	10.2	10.9	10.6	10.5
Sterno-scapularis	6.1	4.9	7.5	6.3	6.8	5.9
Deep pectoral	9.5	9.4	10.7	12.6	12.2	13.2
Rhomboideus	9.8	10.5	10.0	8.8	8.6	8.5
Serratus thoracis	18.9	19.4	19.0	22.3	23.2	22.8
Cartilage of the scapula (dorsal-ventral distance)	5.4	5.7	5.0	5.3	5.4	5.7

APPENDIX XV

Muscle Depth (cm)

<u>Romney group</u>

Muscle	Fresh Animals 5	26	35	Fixed Animals 23	10	R28
Latissimus dorsi	1.2	1.1	1.0	1.3	1.3	1.2
Deltoideus pars acromialis	0.7	1.0	0.8	0.9	0.8	1.0
Deltoideus pars scapularis	1.4	1.1	1.0	1.3	1.6	1.5
Infraspinatus	2.3	2.5	1.9	2.9	3.0	2.7
Teres minor	1.2	1.1	1.1	1.7	1.6	1.6
Supraspinatus	3.2	2.9	2.9	3.7	4.1	3.8
Teres major	1.6	1.4	1.2	1.3	1.5	1.4
Subscapularis	1.4	1.8	1.1	1.4	1.5	1.5
Tensor fascia antibrachii	0.8	1.1	1.0	1.1	1.1	1.3
Triceps (lateral head)	2.3	2.2	2.3	2.6	2.4	2.8
Triceps (long head)	3.1	3.3	3.0	3.2	3.4	3.9
Triceps (medial head)	1.1	1.4	1.0	1.2	1.3	1.2
Biceps brachii	2.5	2.8	2.5	2.8	2.8	2.4
Coraco-brachialis	0.9	0.7	1.1	0.8	0.9	0.8
Brachialis	1.1	1.2	1.1	1.2	1.3	1.1
Anconeus	1.5	1.7	1.6	2.0	2.5	1.9
Trapezius	0.6	0.6	0.8	0.6	0.7	0.6
Brachiocephalicus	1.0	1.1	1.2	1.0	1.1	1.1
Superficial pectoral	1.1	1.2	0.9	1.4	1.2	1.2
Sterno-scapularis	0.8	0.7	0.6	1.0	1.0	0.9
Deep pectoral	1.8	1.8	1.4	2.3	2.5	3.1
Rhomboideus	1.1	1.0	1.3	1.0	1.0	1.1
Serratus thoracis	1.8	2.2	1.8	2.0	2.0	2.2

APPENDIX XV (continued)

Cheviot group

Muscle	Fresh Animals 18	19	55	Fixed Animals 20	24	68
Latissimus dorsi	1.2	1.2	1.2	1.3	1.3	1.4
Deltoideus pars acromialis	1.3	1.1	1.4	1.1	1.0	1.2
Deltoideus pars scapularis	1.4	1.5	1.4	1.8	1.3	1.6
Infraspinatus	2.4	2.4	2.9	3.0	3.0	3.3
Teres minor	1.4	1.2	1.6	1.9	1.8	1.6
Supraspinatus	3.4	3.3	2.6	3.4	3.6	3.9
Teres major	1.7	1.6	1.7	1.8	1.6	1.9
Subscapularis	1.4	1.4	1.1	1.4	1.5	1.6
Tensor fascia antibrachii	1.1	1.1	1.0	0.9	1.2	1.3
Triceps (lateral head)	2.5	2.1	2.5	2.9	2.8	2.8
Triceps (long head)	3.8	3.1	3.5	3.8	3.6	3.8
Triceps (medial head)	1.3	1.2	1.2	1.7	1.1	1.3
Biceps brachii	2.6	2.8	2.1	2.9	2.9	2.7
Coraco-brachialis	1.0	1.2	1.0	1.0	0.9	1.0
Brachialis	1.1	1.4	1.2	1.1	1.2	1.3
Anconeus	1.8	1.8	2.1	2.6	2.1	2.1
Trapezius	0.7	0.6	0.6	0.7	0.6	0.7
Brachiocephalicus + omotr.	1.2	1.4	1.2	1.1	1.1	1.2
Superficial pectoral	0.9	1.4	1.1	1.6	1.4	1.3
Sterno-scapularis	0.7	1.0	0.7	1.1	0.9	0.9
Deep pectoral	1.8	1.7	1.5	3.1	3.8	3.3
Rhomboideus	1.1	1.1	1.3	1.1	0.9	1.5
Serratus thoracis	2.4	2.5	2.0	1.7	1.8	2.1

APPENDIX XVI

Muscle Areas (sq cm)

Romney group

Muscle	Fresh Animals			Fixed Animals		
	5	26	35	10	23	R28
Latissimus dorsi	217.3	266.7	210.8	270.2	274.7	243.3
Deltoideus pars acromialis	18.8	20.0	16.4	27.7	22.9	20.6
Deltoideus pars scapularis	14.0	15.8	12.5	19.2	17.8	16.0
Infraspinatus	93.1	107.5	91.9	112.9	121.7	111.1
Supraspinatus	67.9	76.2	64.3	81.1	75.6	71.1
Teres minor	14.7	16.3	13.7	16.3	14.4	14.5
Teres major	31.6	36.2	31.3	43.1	38.9	36.9
Triceps (long head)	78.4	83.1	72.8	87.2	79.4	71.8
Triceps (lateral head)	35.2	38.7	35.1	41.7	37.4	34.1
Triceps (medial head)	23.8	26.2	16.5	23.7	22.4	19.7
Tensor fascia antibrachii	25.8	25.8	25.7	28.3	29.7	27.7
Anconeus	11.3	9.2	10.2	12.2	12.2	10.4
Brachialis	33.2	35.8	27.1	34.0	34.3	30.8
Coraco-brachialis	20.4	16.8	12.8	21.5	22.4	14.5
Biceps brachii	23.4	25.6	20.5	25.2	27.1	22.3
Subscapularis	92.0	100.5	85.8	106.7	105.7	94.9
Brachiocephalicus + omo-tr	139.2	176.5	143.5	250.7	258.7	216.4
Trapezius	144.9	179.6	125.6	210.8	235.9	196.8
Sterno-scapularis	38.1	37.3	32.0	39.3	34.9	39.6
Superficial pectoral	130.4	146.7	146.4	134.5	139.7	119.4
Deep pectoral	283.6	281.4	246.7	296.3	293.5	242.8
Rhomboideus	88.8	109.6	89.9	92.8	92.4	91.3
Serratus thoracis	344.0	401.7	311.0	386.2	395.4	355.8
Cartilage of scapula	73.2	78.7	68.4	75.7	85.5	72.1

APPENDIX XVI (continued)

Cheviot group

Muscle	Fresh Animals 18	19	55	Fixed Animals 20	24	68
Latissimus dorsi	260.9	238.0	242.0	250.3	252.6	244.0
Deltoideus pars acromialis	23.0	23.0	22.0	27.7	24.1	26.3
Deltoideus pars scapularis	16.2	16.1	18.5	20.7	18.6	16.4
Infraspinatus	110.7	112.6	106.3	108.9	125.5	120.9
Supraspinatus	70.6	75.2	70.0	72.7	71.9	71.8
Teres minor	15.5	15.6	15.6	19.8	17.2	18.5
Teres major	39.6	39.2	41.2	36.1	49.4	44.8
Triceps (Long head)	77.0	85.3	78.5	89.0	81.1	83.2
Triceps (lateral head)	35.8	36.0	43.1	47.7	42.7	39.0
Triceps (medial head)	24.5	26.4	23.9	31.2	27.2	26.7
Tensor fascia antibrachii	27.4	24.7	27.1	34.5	23.2	30.0
Anconeus	13.0	13.2	12.0	14.7	10.6	11.8
Brachialis	29.7	32.4	31.8	34.4	33.5	29.8
Coraco-brachialis	19.6	17.7	16.8	18.3	19.1	17.3
Biceps brachii	21.9	23.5	22.6	24.0	24.2	22.8
Subscapularis	97.1	93.9	100.7	98.9	104.5	104.9
Brachiocephalicus + omotr.	158.1	126.6	147.6	222.7	227.7	210.7
Trapezius	162.8	207.6	150.5	196.4	205.4	205.1
Sterno-scapularis	37.5	32.0	36.9	40.7	35.1	37.3
Superficial pectoral	121.9	124.5	121.3	132.4	135.3	136.6
Deep pectoral	258.7	249.6	253.9	273.7	279.2	277.8
Rhomboideus	88.5	95.3	96.1	85.1	87.3	86.7
Serratus thoracis	307.5	327.4	326.0	392.9	408.8	374.2
Cartilage of scapula	74.5	69.6	79.2	79.0	78.9	77.3

APPENDIX XVII

Muscle Volume (gm)

Romney group

Muscle	Fresh Animals 5	Fresh Animals 26	Fresh Animals 35	Fixed Animals 23	Fixed Animals 10	Fixed Animals R28
Latissimus dorsi	88.4	104.8	72.3	106.3	112.0	89.9
Deltoideus pars acromialis	13.9	16.6	10.2	12.6	15.5	13.0
Deltoideus pars scapularis	12.4	11.7	6.0	11.0	14.3	11.5
Infraspinatus	136.5	169.3	112.9	178.9	189.2	151.5
Teres minor	12.5	14.5	10.5	12.0	12.0	9.5
Supraspinatus	126.4	152.1	115.3	160.2	179.6	147.4
Teres major	25.8	30.6	22.0	29.5	33.2	28.0
Subscapularis	71.8	77.2	62.5	77.6	80.1	71.7
Tensor fascia antibrachii	14.3	17.5	14.9	18.3	14.6	19.1
Triceps (lateral head)	40.8	47.6	43.4	47.4	48.6	48.3
Triceps (long head)	127.3	156.7	115.1	138.3	143.9	149.9
Triceps (medial head)	15.2	16.7	10.4	14.5	14.1	9.6
Biceps brachii	34.9	40.7	30.3	39.3	40.9	29.0
Coraco-brachialis	10.0	11.8	6.6	10.0	15.6	7.2
Brachialis	24.4	26.7	18.0	24.7	28.9	21.3
Anconeus	10.4	8.0	6.8	10.8	10.1	9.3
Trapezius	51.8	57.3	39.4	62.0	69.3	58.3
Brachiocephalicus + omo-tr.	99.9	108.7	81.1	133.3	124.6	109.5
Superficial pectoral	46.6	62.4	42.5	68.8	61.5	56.4
Sterno-scapularis	21.5	21.5	14.6	21.0	22.2	20.9
Deep pectoral	162.2	179.9	131.5	179.3	175.2	185.7
Rhomboideus	54.8	67.0	48.0	59.9	57.5	51.5
Serratus thoracis	260.1	346.2	222.5	321.5	298.6	285.8
Muscles of the fore arm	158.6	175.6	142.6	173.7	180.7	150.0

APPENDIX XVII (continued)

Cheviot group

Muscle	Fresh Animals 18	19	55	Fixed Animals 20	24	68
Latissimus dorsi	106.3	118.9	100.0	95.1	94.5	107.3
Deltoideus pars acromialis	17.8	18.2	18.5	10.5	17.0	18.0
Deltoideus pars scapularis	13.1	16.3	16.1	22.6	10.7	14.6
Infraspinatus	158.9	164.1	174.2	180.1	184.1	191.3
Teres minor	11.7	11.3	13.9	13.2	11.8	12.1
Supraspinatus	143.8	151.3	134.3	163.3	151.3	146.6
Teres major	36.1	31.5	37.4	32.1	37.7	35.7
Subscapularis	72.0	70.3	72.8	82.9	83.4	76.3
Tensor fascia antibrachii	15.3	17.4	17.4	26.5	20.3	17.5
Triceps (lateral head)	52.0	43.0	57.1	60.2	53.3	56.7
Triceps (long head)	152.8	137.3	155.0	165.7	151.2	153.8
Triceps (medial head)	15.7	18.2	16.7	23.4	14.9	15.0
Biceps brachii	32.7	36.0	34.3	36.5	39.5	34.8
Coraco-brachialis	11.6	15.0	10.7	15.7	10.3	11.0
Brachialis	21.2	27.4	24.9	24.8	20.5	24.0
Anconeus	13.4	13.4	13.2	21.1	11.5	10.0
Trapezius	51.0	84.4	54.7	49.2	55.0	68.6
Brachiocephalicus + omotr.	101.7	90.1	100.9	107.1	106.0	125.8
Deep pectoral	173.1	165.1	144.9	171.9	170.6	172.8
Superficial pectoral	49.0	53.6	54.1	66.9	50.0	58.1
Sterno-scapularis	16.9	18.2	17.8	20.2	18.1	18.0
Rhomboideus	50.8	48.1	49.6	47.4	47.0	56.1
Serratus thoracis	252.8	280.1	281.5	283.5	249.4	290.3
Muscles of the fore arm	149.8	152.2	159.7	181.2	153.9	146.5

APPENDIX XVIII

Ratios of Weight to Length in the Bones

Sheep No.	Metacarpus Length (cm)	Metacarpus Weight (gm)	Metacarpus Ratio	Humerus Length (cm)	Humerus Weight (gm)	Humerus Ratio	Scapula Length (cm)	Scapula Weight (gm)	Scapula Ratio	Radius-ulna Length (cm)	Radius-ulna Weight (gm)	Radius-ulna Ratio
ROMNEYS												
5	10.7	40.9	3.82	14.1	112.6	7.99	11.6	87.1	7.51	17.9	87.5	4.89
26	12.2	45.3	3.71	14.6	124.4	8.52	12.5	98.5	7.88	19.1	98.1	5.14
35	10.4	34.1	3.28	13.8	92.8	6.73	11.0	64.6	5.87	17.8	69.2	3.89
23	12.7	38.6	3.04	14.8	115.3	7.79	12.1	86.4	7.14	17.8	80.3	4.51
10	11.2	45.9	4.10	14.8	123.9	8.37	11.4	83.0	7.28	19.5	85.3	4.37
R28	11.0	35.0	3.18	13.9	90.8	6.53	11.7	73.8	6.31	17.3	68.7	3.97
11	11.3	39.7	3.51									
27	10.9	39.8	3.65									
44	10.3	34.4	3.34									
Cheviots												
18	11.9	37.3	3.13	14.2	100.7	7.09	11.9	78.0	6.56	18.9	78.6	4.16
19	11.5	37.7	3.28	14.0	104.2	7.44	12.1	78.1	6.46	18.1	80.9	4.47
55	11.9	36.3	3.05	14.1	98.3	6.97	11.9	71.5	6.01	18.8	72.9	3.88
20	11.4	40.2	3.53	14.4	122.4	8.50	11.4	85.5	7.50	19.2	91.0	4.74
24	12.1	37.1	3.07	14.0	97.9	6.99	11.8	76.9	6.52	18.6	70.1	3.77
68	11.6	38.5	3.32	14.1	103.2	7.32	12.4	81.1	6.54	18.4	75.5	4.10
17	11.6	36.5	3.15									
C28	11.2	38.4	3.43									
30	11.9	39.5	3.32									

APPENDIX XIX

Total Tissue Weights
(gm)

Romney group

Sheep No.	Muscle	Bone	Fat and Tendon
5	1679.2	305.8	695.7
26	1994.8	339.5	1119.7
35	1421.5	241.2	644.5
23	1954.8	304.0	1061.0
10	1991.5	308.8	634.9
R28	1798.9	248.3	956.7

Cheviot group

Sheep No.	Muscle	Bone	Fat and Tendon
18	1790.2	273.7	721.2
19	1856.4	277.8	388.4
55	1832.7	260.9	452.9
20	1958.7	318.0	382.1
24	1815.6	263.7	506.0
68	1917.0	277.5	370.4