CARCASS DEVELOPMENT AND CELLULAR GROWTH OF MUSCLE AND FAT IN MALE AND FEMALE CATTLE

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ABSTRACT

The influence of sex on muscle, fat and bone growth from birth to maturity was investigated by complete dissection of a half carcass of 18 female and 21 male Jersey cattle. In addition, the cellular growth of five muscles: *mm. rhomboideus, splenius, longissimus capitis, longissimus* and *semitendinosus*, and of three fat depots: subcutaneous, intermuscular and perirenal, was examined. Transverse sections of the five muscles were stained for myosin adenosine triphosphatase (ATPase) activity.

Muscle development, especially in the forequarter, is greater in males than in females. In males, the allometric growth of the neck muscles, *mm. rhomboideus, splenius and longissimus capitis*, relative to total muscle weight, was in two phases with two significantly different regression slopes, which describe the growth better than a single regression equation. The second phase had a significantly higher regression coefficient. In contrast, the growth of the neck muscles in females, and the growth of *mm. longissimus* and *semitendinosus* in both males and females, could be described satisfactorily by a single regression equation.

The transverse sectional area of whole muscle and the mean fibre area, which was determined in fresh frozen sections, enabled the estimation of total fibre number in each of the five muscles. Fibre number did not change significantly during growth. Males had about double the number of fibres in these neck muscles as compared with females; functional differences between sexes were reflected in the difference in number and the rate of increase in size of myosin ATPase high fibres.

These results support the concept that sexual dimorphism of overall muscle growth and muscle distribution in all species, is attributable to differences in prenatal development of fibre number, which determines the potential of a muscle to grow.

Differences in fat growth between sexes were due to the overall rate of fat deposition; the order of partitioning was in general

similar between sexes. The allometric growth of the three fat depots relative to total side fat shows that in both sexes, subcutaneous fat was the fastest growing, intermuscular was intermediate, and perirenal was slowest. Between sexes, the growth ratios of all three depots were higher in females than in males; a significant difference was observed for subcutaneous fat.

Determination of total lipid content of each depot, and lipid content of an adipocyte, allowed estimation of adipocyte number. Adipose tissue growth in all three depots of both sexes is characterised by a greater increase in the size of adipocytes than an increase in their number. However, the increase in size of adipocytes did not explain differences in the rate of fat growth between sexes and between depots. The rate of increase in adipocyte number was higher in females than in males for all three depots; the order of the rate of increase in number parallels the order of the growth ratios of the fat depots. Thus sex differences in the rate of fat growth can be attributed to differences in the rate of increase in the number of adipocytes.

Sex differences in bone weight distribution were small. In both sexes, there was a proximodistal gradient of decreasing growth in the limbs; craniocaudally, there was a fluctuating growth gradient in the vertebrae, and an increasing gradient in the ribs. Growth ratios of individual bones suggest a faster developing forequarter in males than in females; the forelimb may be more important for propulsion in males than in females.

External and internal pelvic measurements indicate differences in shape between sexes. From this model, it was suggested that problems of dystocia may arise when female adaptive changes in the vertical plane do not occur postnatally.

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1.0 INTRODUCTION

Males and females differ in their rate, range and quality of growth. In meat production, the quality of growth is judged by a grading system which assesses the suitability of a carcass for a particular market. The influence of sex on carcass composition and quality (Preston and Willis, 1974), is recognised in the New Zealand beef export grading system which has three separate classifications for bulls, cows, and steers and heifers (New Zealand Meat Producers Board, 1975). Thus the sex of an animal is a relevant consideration in animal production.

The influence of sex on carcass composition has been investigated in cattle (Brännäng, 1966, 1971; Berg and Mukhoty, 1970; Mukhoty and Berg, 1971, 1973, 1974; Bergström, 1978; Jones, Price and Berg, 1980), sheep (Fourie, Kirton and Jury, 1970; Lohse, 1973; Jury, Fourie and Kirton, 1977) and pigs (Fowler, Taylor and Livingstone, 1969; Hansson, Lundström and Malmfors, 1975; Davies, Pearson and Carr, 1980). These studies have compared and described the growth patterns of muscle, fat and bone of different sexes, but have not provided an underlying mechanism to account for any differences observed. The functional explanation given for the growth of neck and abdominal muscles (Berg and Butterfield, 1976) answers the question 'why?' but does not answer the question 'how?' In order to elucidate the mechanism, the biological aspects of growth must be investigated.

Growth is achieved by a change in cell number and/or size. Through the process of cell differentiation and secretion of extracellular substances, different tissues are produced. The carcass composition of an animal at birth is therefore the result of antenatal cell growth and differentiation. In animal production, the number and size of muscle, fat and bone cells and the extent to which these cells multiply postnatally, determines the potential of an animal to grow and also the carcass composition of the animal at any stage of its growth. Carcass composition is the manifestation of complex genetic and environmental factors interacting on cells. Therefore, a study of cellular growth should provide a better understanding of growth patterns, especially if investigated in combination with a growth study, using a total carcass dissection method (Walker, 1961; Butterfield, 1964a).

This thesis examines the cellular growth of certain muscles and fat depots in conjunction with the carcass development of male and female cattle, from birth to maturity. Males and females were compared because the effects of sex are best demonstrated in animals with clear cut genotype and phenotype. Castrated males are omitted as they do not represent a true sex, having a genotype of a male and a phenotype similar to a female. Inclusion of castrates would demonstrate the effects of castration rather than of sex.

The time-independent allometric equation, $y = a.x^b$ (Huxley, 1924, 1932), where b is the differential growth ratio, has been used to study carcass composition (Elsley, McDonald and Fowler, 1964; Tulloh, 1964; Butterfield and Berg, 1966a,b; Seebeck, 1967, 1973a,b; Seebeck and Tulloh, 1968a, b; Fourie *et al*, 1970; Mukhoty and Berg, 1971, 1973; Davies, 1974a,b; Jury *et al*, 1977). This empirical equation recognises the multiplicative nature of growth (Huxley, 1932; Medawar, 1950). It is especially useful in its logarithmic form of $\log y = a + b \log x$ because in this linear form it allows comparison of b values (Seebeck, 1968). Statistically a double logarithmic regression, is used here to show the effects of sex on the change in tissue and cellular proportions over a complete range of postnatal growth.

Sex differences in external appearance between adults are more evident in cattle than in sheep or pigs. Of the cattle breeds, Jerseys subjectively show this difference particularly well. The change in shape of a calf at birth to sexually dimorphic adults at maturity is simulated by Cartesian transformation (Thompson, 1917) in Fig 1. The neck region is especially dimorphosed and this is associated with differences in muscle weight distribution between sexes (Mukhoty and Berg, 1971, 1973; Bergström, 1978). The recent results of Bergström (1978) indicated which neck muscles are

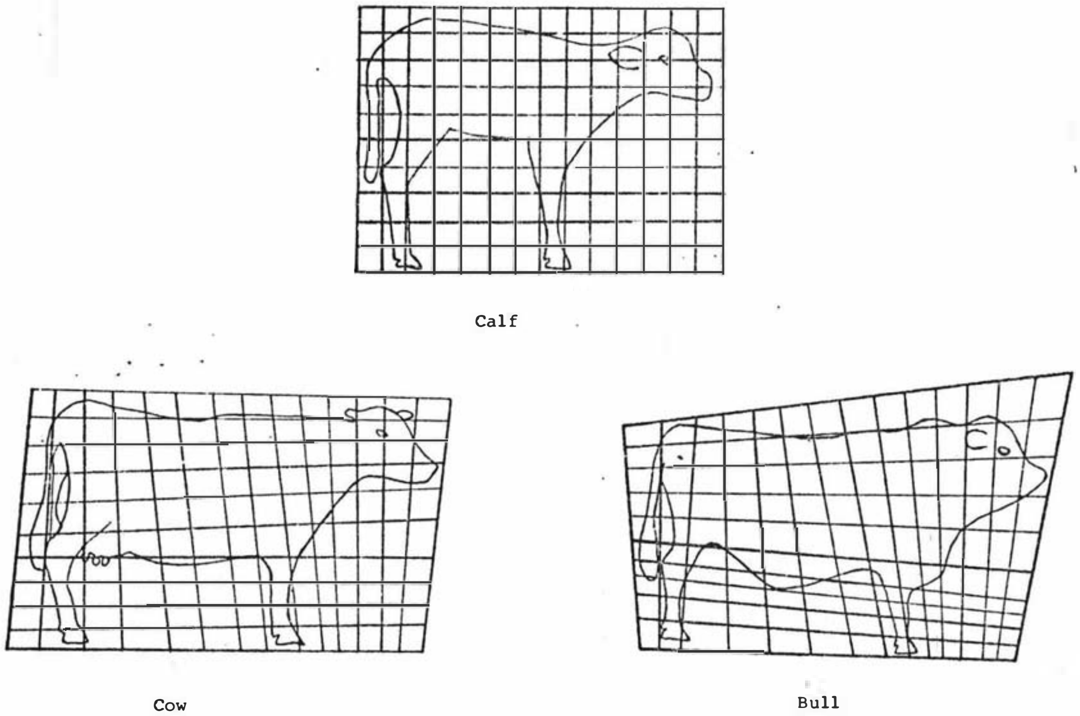


Figure 1: Cartesian transformation (Thompson, 1917) of body shape in cattle

different between bulls and cows. When the present study was commenced, evidence from experiments on sheep (Lohse, 1973; Jury *et al*, 1977), deer (G.Y. Tan and P F. Fennessy, unpublished) and castrated cattle (Brännäng, 1971) indicated that *mm. rhomboideus, splenius* and *longissimus capitis et atlantis* are muscles affected by sex, while *mm longissimus* and *semitendinosus* are unaffected. In this experiment, the overall growth of carcass muscles was studied, but special attention was given to these five muscles. Also, *m. longissimus capitis* was dissected singly and not as *m. longissimus capitis et atlantis*, as both muscles are separable (Smuts, 1976).

The relative growth of muscles does not necessarily show constant allometry (Butterfield and Berg, 1966a, Lohse, Moss and Butterfield, 1971; Lohse, 1973; Jury *et al*, 1977; Bergström, 1978). Biologically, a change in allometry signifies a change in the internal environment of the animal (Bertalanffy, 1960). In this study, examination for breaks in the allometric growth of the five muscles may demonstrate a difference in internal environment between the bull and the cow; some or all of the difference may be due to the effect of sex on cellular growth. An estimation of cellular content is therefore relevant to the understanding of the growth of these muscles. The present work attempts to relate differences in muscle fibre number and rate of increase in fibre size with differences in muscle growth between sexes. The use of the myosin adenosine triphosphatase (ATPase) histochemical technique provides further information on any functional differences (Davies and Gunn, 1972) in these muscles between males and females.

The growth of fat varies between regions in the body (Callow, 1948; 1962; Seebeck and Tulloh, 1968a; Johnson, Butterfield and Pryor, 1972; Kempster, Cuthbertson and Harrington, 1976; Kempster, Avis and Smith, 1976; Berg, Anderson and Liboriussen, 1978c) and is influenced by the number and growth potential of adipocytes present in each region. Dissectible fat is the visible product of lipid accumulation in substantial numbers of adipocytes. The appearance of dissectible fat must arise from pockets of cells representing centres of growth. As such, subcutaneous fat originates from various centres which expand and encroach on one another, as the animal becomes fatter. It was necessary to identify these centres, using anatomical landmarks, before each could be dissected and the growth changes in the distribution of subcutaneous fat determined. There has been no previous anatomical description of the development of subcutaneous fat growth centres over the entire carcass surface for any species.

Sex differences in fat deposition has been investigated in heifers and bulls (Berg *et al*, 1979; Jones, Price and Berg, 1980). However differences in cellular growth of fat between males and females have not been studied in meat animals. Meat animal studies (*cattle*: Hood and Allen, 1973; Schön, 1978, Truscott, Wood and Denny, 1980; *sheep*: Haugebak, Hedrick and Asplund, 1974; Hood and Thornton, 1979; Broad, Davies and Tan, 1980; *pigs*: Lee, Kauffman and Grummer, 1973a,b) have been limited to comparisons of fat cellularity between fat depots, and at the same bodyweight or age. Lemonnier (1971, 1972) has shown that male and female rats differ in adipocyte number and size; Sjöström *et al*. (1972) and Krotkiewski *et al*. (1975) have demonstrated regional differences in adipose cellularity in biopsy samples from men and women. In the present study, samples representing subcutaneous, intermuscular and perirenal fat depots are estimated for adipocyte number and size. The relative importance of increasing adipocyte number and size with increasing fatness was examined for each depot and sex.

It is expected that any sex effect on the muscular system will also affect the skeletal system. Jones, Price and Berg (1978) did not demonstrate a sex difference on the growth of individual bones relative to total bone. The present study, however uses a single breed, covers a wider postnatal growth range and studies individual vertebrae and ribs. In this way any sex differences in growth gradients, craniocaudally, along the vertebral column and ribs, could be demonstrated. Linear measurements of bones, in particular those of the pelvis, are investigated for sexual dimorphism.

In summary, the present study attempts new findings on cattle growth.

1. It investigates changes in tissue distribution in cows and bulls from birth to maturity in a single breed.
2. It combines studies of gross anatomical and cellular growth of muscle and fat.
3. It examines the cellular growth patterns of muscles known to be sexually dimorphic.
4. It assesses the functional differences between sexes in those muscles using a relevant histochemical technique.
5. It identifies the location of subcutaneous fat growth centres.
6. It examines the cellular growth patterns in samples from subcutaneous, intermuscular and perirenal fat depots and compares these patterns between sexes.
7. It studies the growth gradients in limbs and axial skeletons of both sexes.
8. It compares the growth changes in bone dimensions and in particular the pelvic dimensions between sexes.

An abstract on the work on muscle growth has been published as Tan and Davies (1980).

2.0 MATERIALS AND METHODS

2.1 NUMBER OF CATTLE AND SOURCES OF ANIMALS

Between May 1977 and October 1978, thirty-nine Jersey cattle were slaughtered at various weights to cover a logarithmic weight range from birth to maturity; these included twenty-one males ranging from 20 to 673 kg liveweight and nineteen females ranging from 20 to 414 kg liveweight. The individual liveweights are given in Appendices 4 and 5.

Animals were obtained from pasture based farms within a 25 km radius of Palmerston North, New Zealand. Of these animals, twelve of each sex were from a dairy herd belonging to Massey University and four males were from the Artificial Breeding Centre at Awahuri. All animals were in good condition on ante-mortem inspection. Since the author had no control over the environment of the animals, this study compares the growth of body components relative to each other, rather than their time rate of growth.

2.2 LINEAR MEASUREMENTS

Immediately prior to slaughter, the following linear measurements were carried out on the animals, using a tape measure.

1. Crown-rump = from the intercornual protuberance of the skull to the sacrococcygeal joint
2. Minimum neck circumference
3. Height at withers = the highest point of the thoracic region
4. Width between tuber coxae
5. Width between tuber ischii

These measurements are given in Appendices 4 and 5.

2.3 SLAUGHTER PROCEDURE AND DIVISION OF THE CARCASS

Except for unweaned calves which were slaughtered on the day of delivery, all animals were starved overnight in a pen with readily available water prior to slaughter. The slaughtering procedure differed from that used in an abattoir. It was designed with the following objectives;

1. The right side of the carcass was to be used for dissection while the left side was to be used for the sampling of muscles and fat depots.
2. The vertebral column, sternum and pelvis were not to be bisected.
3. Damage in the neck, especially the muscles to be sampled, was to be avoided.
4. Subcutaneous fat depots such as the perianal depot which might be lost in commercial slaughtering should remain on the carcass.

Animals were stunned with a captive bolt and then bled by severing the left carotid and left jugular vein. During skinning and evisceration, muscle and fat samples for histology and chemical analysis were taken from the left side of the carcass, as described below. The skin was not removed from the head, manus and pes. Only two coccygeal vertebrae were left on the carcass, while the other coccygeal vertebrae were removed along with the skin.

Appendix 1 is the worksheet used and indicates the various structures that were removed and weighed at slaughter. The boundaries of the udder or cod fat were as follows:

Cranial limit	=	lumbosacral junction
Caudal limit	=	caudal edge of the symphysis pubis
Lateral limit	=	ventral border of *m. cutaneus trunci*

The weight of this depot was later halved.

The left thoracic limb was removed by severing *mm. trapezius, omotransversarius, brachiocephalicus, latissimus dorsi, pectoralis superficialis, pectoralis profundus, serratus ventralis* and *rhomboideus*. The left pelvic limb was detached by cutting *mm. gluteus medius, gluteus profundus, biceps femoris, semimembranosus, semitendinosus, tensor fasciae latae, sartorius, gracilis, adductor* and *pectineus*, followed by severance of the ligament of the head of the femur and disarticulation. The left rib cage was removed at the costochondral junctions and disarticulated from the vertebral column. The left abdominal wall was separated from the right, along the *linea alba*.

Thoracic, abdominal and pelvic viscera were dissected into various organs (Appendix 1B). Subtraction of the weight of gut content from liveweight gave an estimation of empty body weight. The weight of the gut included the weights of omental and mesenteric fats.

As much as possible of cavity, perinephric and pelvic fats was removed at slaughter, the remainder was dissected later. Cavity fat was all the fat removed from the thoracic cavity. Demarcation between perinephric (kidney) and pelvic (channel) fats was the transverse plane just passing through the ventral edge of the symphysis pubis and the caudal ventral corner of the last lumbar vertebrae (Williams and Bergström, 1976). Fat from both left and right sides was dissected out and their weights were later halved for each of the depots.

Carcasses were not split longitudinally, but were divided into 'forequarter' and 'hindquarter' by cutting along the caudal edge of the twelfth rib and continuing in the same plane to sever both left and right *m. longissimus*. The vertebral column was then sawn at right angles through the twelfth thoracic vertebra. The 'forequarter' and 'hindquarter' were weighed, covered with plastic and stored between 0°C and 4°C awaiting dissection.

2.4 CARCASS DISSECTION

2.4.1 DISSECTION OF SUBCUTANEOUS FAT

The distribution of subcutaneous fat on the right side of the carcass is described below and shown in Fig.2. The demarcations into different regions were in general based on the muscles over which the fat was deposited. The weights of fat and fascia dissected from the regions in the forequarter and hindquarter were recorded on worksheets shown in Appendices 2 & 3.

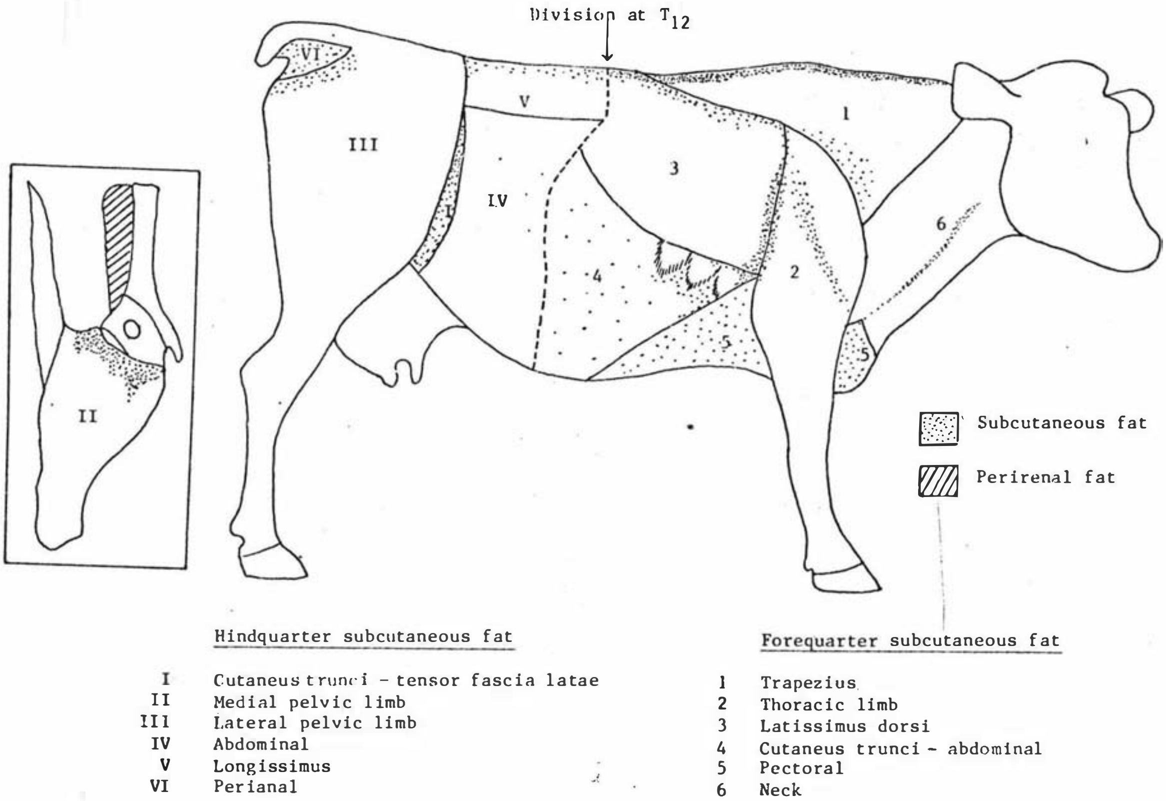


Figure 2: Distribution of subcutaneous fat depot (*M. cutaneus trunci* has been removed). Inset is the medial view of the pelvic limb to show the location of subcutaneous fat II.

2.4.1.1 Forequarter subcutaneous fat

1. Trapezius subcutaneous fat

This was fat found on *m. trapezius* and was often deposited along the dorsal border of the muscle where the muscle originates. Occasionally, some fat was present dorsal to the scapular spine where the muscle inserts by a flat aponeurotic sheet.

2. Thoracic limb subcutaneous fat

All this fat was found on the lateral aspect of the proximal thoracic limb and especially over *m. tensor fasciae antebrachii* and the caudal edge of *m. triceps brachii caput longum*. Also, occasional deposits of fat were observed on the aponeurotic origin of *m. deltoideus*, covering *m. infraspinatus*.

3. Latissimus dorsi subcutaneous fat

Fat on *m. latissimus dorsi* was concentrated dorsally along the ventral edge of *m. trapezius pars thoracica* and cranially along *m. tensor fasciae antebrachii*.

4. <u>Cutaneus trunci - abdominal subcutaneous fat</u>

M. cutaneus trunci was removed and cleaned of fat. Included in this fat was any dissected from the area delimited by the ventral edge of *m. latissimus dorsi*, dorsal border of *m. pectoralis ascendens* and the cut edge where the carcass was divided into 'quarters'. The fat deposits were usually diffuse in a network of subcutaneous fascia.

5. <u>Pectoral subcutaneous fat</u>

Fat on the surface of *mm. pectoralis superficialis* and *profundus* occurred as a firm solid layer in very fat animals. In carcasses with very little external fat covering, fat was absent or scattered randomly over the surface of the muscle.

6. <u>Neck subcutaneous fat</u>

This was fat from the neck region which had not yet been dissected of subcutaneous fat. Usually there was no dissectible fat although occasionally some was found along the jugular groove.

2.4.1.2 <u>Hindquarter subcutaneous fat</u>

I <u>Cutaneus trunci - tensor fasciae latae subcutaneous fat</u>

This was fat found beneath *m. cutaneus trunci*, immediately ventral to the tuber coxae and cranial to *m. tensor fasciae latae*. Fat was present in this location in all carcasses.

II <u>Medial pelvic limb subcutaneous fat</u>

Most of this fat was proximal, especially around the origins of *mm. sartorius, gracilis* and *semimembranosus*. Fat was present in this location in all carcasses.

III <u>Lateral pelvic limb subcutaneous fat</u>

All this fat was found proximally especially in the region immediately cranial to the dorsal edge of the sacrotuberous ligament.

IV Abdominal subcutaneous fat

Similar to the forequarter (Region 4), the fat deposits were sparse and diffuse especially for carcasses with little external fat cover.

V Longissimus subcutaneous fat

Deposits on *m. longissimus* were in general not heavy. When present, the deposits were heavier medially than laterally.

VI Perianal subcutaneous fat

This fat was dissected caudal to the sacrotuberous ligament and around the anus.

Following dissection of subcutaneous fat, each quarter was dissected into its individual muscles, individual bones and fat groups. Identification of muscles was based on the description by Butterfield and May (1966) and Getty (1975).

2.4.2 DISSECTION OF THE FOREQUARTER

Individual muscles were dissected and grouped in the order shown in Appendix 1 C to F. They were placed in covered trays, lined with damp paper towels. As soon as possible, muscles were cleaned of intermuscular fat, fascia and tendon, and were weighed. The intermuscular fat was partitioned and weighed into groups (Appendix 2), which corresponded in general to the muscle groups from which they were dissected. Fascia, tendon and scrap (blood vessels, nerves, lymph nodes and glands) were collected in polythene bags for weighing on completion of the forequarter dissection.

Sterna1 fat, considered a special type of intermuscular fat, was dissected from the external and ventral surface of the sternum. Fat remaining in the thoracic cavity was dissected out and weighed as cavity fat.

Bones were cleaned of remaining muscle and fat, and weighed (Appendix 1 G); the weight of muscle constituted the scrap muscle of the respective muscle groups (Appendix 1 C to F), while the fat was weighed into three groups (Appendix 2), depending on the bones from which it was dissected. As the vertebral column and sternum were not bisected, separation into scrap muscle and fat was carried out only on the right hand side (RHS) of the bones. On the left hand side (LHS), all tissues were indiscriminately dissected and weighed as the LHS scrap.

The vertebral column was separated into cervical and thoracic regions and the lengths of these were recorded. During dissection into individual cervical and thoracic vertebrae for weighing, the spinal cord and fat were removed from the vertebral canal and weighed separately.

Linear measurements using vernier calipers and tape measure were carried out on some bones (Appendix 1 G). The width is the minimum craniocaudal dimension, while the length is as follows:

Cervical vertebrae:	From the cranial edge of the ventral arch of the first cervical vertebra to the caudoventral edge of the body of the seventh cervical vertebra
Thoracic vertebrae:	From the cranioventral edge of the body of the first thoracic vertebra to the caudoventral edge of the body of the transected twelfth thoracic vertebra
First and eighth ribs:	Articular surface of the tubercle to the sternal end
Scapula:	Dorsal edge of cartilage to glenoid cavity
Humerus:	Apex of *tuberculum majus pars cranialis* to the distal articular surface of lateral condyle
Radius:	Proximal to distal extremity
Ulna:	*Tuber olecrani* to *processus styloideus*
Metacarpus III and IV:	Proximal to distal extremity

Following dissection of the neck muscles, the head was removed and weighed. Muscles of mastication were dissected from the skull. Using a sharp scalpel, *mm. pterygoideus medialis* and *pterygoideus lateralis* were partially detached from their origins and insertions.

Disarticulation of the temporomandibular joint, by depressing the mandible, permitted enough exposure of the muscles for complete detachment. The weights of the head and muscles of mastication were not included in the estimation of total side muscle (TSM).

The mandible was cleaned and weighed, and then measured linearly as follows:

Height: Apex of *processus coronoideus* to the ventral edge of the angle of the mandible

Length: Caudal edge of the ramus to the symphysis.

2.4.3 DISSECTION OF THE HINDQUARTER

As for the forequarter, individual muscles, dissectible fat depots and bones were dissected and weighed (Appendices 1 & 3). Perirenal and channel fat were removed from both the left and right side of the carcass; the mean weight of each depot was used to reduce errors due to asymmetry.

The lengths of thoracic, lumbar, sacral and caudal regions were measured. The sacrum was left fused with the os coxae. The following bone dimensions were measured:

Thoracic vertebrae:		Cranioventral edge of the body of the transected twelfth thoracic vertebra to the caudoventral edge of the body of the thirteenth thoracic vertebra
Lumbar vertebrae:		Cranioventral edge of the body of the first lumbar to the caudoventral edge of the body of the sixth lumbar vertebra
Sacrum:		Cranial end of the first and caudal end of the fifth sacral vertebra
Caudal vertebrae:		Total length of the first two caudal vertebrae
Os coxae:	(a)	Direct distance between *tuber ischii*
	(b)	Direct distance between *tuber coxae*
	(c)	Conjugate diameter which is from the cranial end of the pubic symphysis to the promonotory of the sacrum

	(d) Transverse diameter which is the greatest width of the cranial pelvic aperture
	(e) Vertical diameter which is the vertical distance from the cranial end of the pubic symphysis to the roof of the pelvic cavity
Femur:	Apex of *trochanter major* to distal articular surface of lateral condyle
Tibia:	Medial tubercle of intercondyloid eminence to medial malleolus
Metatarsus III and IV:	Proximal to distal extremity

The raw data of the dissections are given in Appendices 4 and 5.

2.5 MUSCLE SAMPLES

2.5.1 POSITION OF MUSCLE SAMPLES

The approximate positions where the left *mm. rhomboideus, splenius, longissimus, capitis, longissimus* and *semitendinosus* were transected, their transverse whole muscle area (WMA) traced and samples taken for enzyme histochemistry, are as follows:

M. rhomboideus:	Between the sixth and seventh cervical vertebrae
M. splenius:	Between the third and fourth cervical vertebrae
M. longissimus capitis:	Between the fifth and sixth cervical vertebrae
M. longissimus:	Between the twelfth and thirteenth thoracic vertebrae
M. semitendinosus:	Immediately distal to the tendinous intersection

The WMA of each muscle was drawn on paper and was determined by a paper weighing method. Muscle samples of up to $2cm^2$ in transverse sectional area were removed from the same superficial region of each muscle. They were packed in plastic bags and immediately deep frozen at $-20^{\circ}C$. Sectioning was carried out within one month of storage.

2.5.2 ENZYME HISTOCHEMISTRY

For sectioning, the frozen samples were thawed over a period of up to

20 min, trimmed and then rapidly frozen by plunging into 2-methylbutane (BDH, C_5H_{12}), which had been cooled with liquid nitrogen. 10μm thick sections were cut at -20°C, transferred to slides and allowed to thaw and dry rapidly at room temperature. Myosin ATPase activity in these sections was demonstrated using the modified calcium-cobalt method of Padykula and Herman (1955) as described by Davies and Gunn (1972).

2.5.3 ESTIMATION OF MEAN FIBRE AREA

Sections were examined using a projection microscope. The outlines of a micrometer scale and areas containing high and low myosin ATPase fibres, totalling about 400 individual fibres, were back projected and traced on transparent paper. The number of fibres of each fibre type were counted and the proportions calculated. The areas of paper containing each fibre type were weighed to give an estimate of the proportion of the WMA occupied by each fibre type. From the above information it was possible to calculate the mean fibre area (MFA), the mean ATPase high fibre area and the mean ATPase low fibre area.

2.6 FAT SAMPLES

2.6.1 FAT SAMPLING SITES

Approximately 1 cm^3 fat samples, representing subcutaneous, intermuscular and perirenal depots, were taken from three sites, identified as follows:

(a) Subcutaneous fat: Fat beneath *m. cutaneus trunci* immediately ventral to *tuber coxae*

(b) Intermuscular fat: Fat immediately cranial to the scapula, beneath *mm. trapezius, omotransversarius* and *brachiocephalicus*

(c) Perirenal fat: Fat overlying or adjacent to the cranial pole of the left kidney

2.6.2 FAT HISTOLOGY

The fat samples were fixed for 7 min in 35% formaldehyde at room temperature, and then washed with and stored in Krebs-Ringer bicarbonate solution (De Luca and Cohen, 1964), but containing half of the suggested concentration of calcium ions. The samples were frozen, sectioned on a cryostatic microtome (Sjöström, Björntorp, Vrána, 1971); the sections were transferred to slides where they were mounted in a water-based mountant and covered with a coverslip. The thickness of the sections were 50, 100-150 or 200-250 μm, depending on the size of the fat cells.

The lipid contents of cell from selected sections of fat at different stages of growth were demonstrated with Sudan black and oil red O stains (Culling, 1974); their nuclei were observed on counter-staining oil red O sections with Mayer's haematoxylin, and were also shown in other sections stained with acridine orange and visualised with UV-fluorescent microscopy (Lorch and Rentsch, 1969).

2.6.3 ESTIMATION OF MEAN FAT CELL VOLUME

With a projection microscope, fat sections were examined and the outlines of over 200 randomly selected adipocytes were traced on transparent paper. At the same magnification, an objective micrometer scale was traced to provide a ready ruler for measuring adipocyte diameter. The mean diameter ($\bar{d}$) of the adipocytes and its standard deviation (s) were calculated. The mean adipocyte volume was obtained using the formula of Goldrick (1967): $(\pi/6)(3s^2 + \bar{d}^2)\bar{d}$. The lipid content (μg) per adipocyte (LIPA) was thus calculated assuming a lipid density of 0.92 $g.cm^{-2}$ for bovine fat (Fidanza, Keys and Joseph, 1953).

2.6.4 CHEMICAL ANALYSIS OF FAT

Fat samples representing the three fat depots were analysed for lipid content by a modified method of Atkinson, Fowler, Garton and Lough (1972) as described by Clark and Tarttelin (1976). Duplicate samples each weighing about 1 g were freeze-dried, weighed and lipid extracted. The percentage of fat in the freeze-dried sample was calculated as follows:

$$\frac{V_c \times W_f}{(V_s - (V_f \times W_f)) \times W_s} \times 100\%$$

where V_c = volume of chloroform in solvent mixture (7.5 ml);

W_f = weight of fat after evaporation of sample

V_s = volume of chloroform sample after fat extraction (about 5 ml);

V_f = volume of 1 g of fat dissolved in chloroform (1.08 ml); and

W_s = weight of freeze-dried sample.

If the difference between duplicates was no greater than 5%, the mean of the two values was taken; otherwise further analyses were made.

2.7 ANALYSIS OF DATA

All data were transformed into logarithms and examined by standard linear regression analysis. The regression coefficient *b*, in a double logarithmic regression, is the differential growth ratio (Huxley, 1924) of a component *y* relative to another, *x*. Using the test quotient *t* and at the 5% or 1% level of significance, values of *b* were tested for:

(1) the significance of the difference between *b* and 1; and
(2) the significance of the difference between sexes in their values of *b* for the same two body components.

Where appropriate, values of log *y* and its variance for a given value of log *x* were estimated in each sex from their respective allometric equations. The significance of the difference between the two values of log *y* was estimated by comparing the 95% or 99% confidence limits for the values of log *y*; when these limits do not overlap, the values of log *y* and therefore *y* are significantly different (Barr, 1969).

In addition, the growth of testes, and of *mm. rhomboideus, splenius, longissimus capitis, longissimus* and *semitendinosus* in male and female cattle, relative to TSM were examined as follows:

(1) For each relationship, a single regression was fitted. The y values were plotted against the x value (TSM) on a double logarithmic scale and inspected for linearity.

(2) Where a break in allometry was suspected on inspection, two regressions were fitted in order to reduce the residual sum of squares.

(3) In each case, an F test, comparing the mean squares of the single regression with that of the two regressions, was used to determine whether two regressions were significantly better than a single regression in representing its relative growth. The mean squares of the single regression was obtained by dividing its residual sum of squares by its number of degrees of freedom, d_1; $d_1 = n_1 - 2$, where n_1 is the number of observations in the single regression. The mean squares of the two regressions was obtained by dividing their total residual sum of squares by their total number of degrees of freedom, d_2; $d_2 = n_2 + n_3 - 4$, where n_2 and n_3 are the number of observations in each of the two regressions.

(4) If the F ratio was significant at 5% or 1% level of significance, then the two regressions were significantly better than a single regression and were therefore used to describe the allometric relationship; if not significant, then a single regression was used.

3.0 RESULTS AND DISCUSSIONS

3.1 CARCASS GROWTH

3.1.1 RESULTS

3.1.1.1 Relative growth of fat, muscle and bone

The allometric growth equations relating total side fat (TSF), muscle (TSM) and bone (TSB) to half carcass weight (HCWT) and total side muscle plus bone (TSMB), in male and female Jersey cattle are given in Table 1 and Fig. 3. Regardless of the independent variable, the order of tissue growth was similar for each sex. All three tissues

Table 1: Double logarithmic regressions comparing the growth of total side fat (TSF), total side muscle (TSM), total side bone (TSB), forequarter fat (FQF), forequarter muscle (FQM), forequarter bone (FQB), hindquarter fat (HQF), hindquarter muscle (HQM) and hindquarter bone (HQB), relative to half carcass weight (HCWT) and total side muscle plus bone (TSMB), between 21 male and 18 female Jersey cattle, from birth to maturity. Weights are in grammes.

		Male				Female		
Variable x	Tissue y	Growth Ratio b_{Φ}	s_b	Constant	Sex Diff.	Growth Ratio b_{Φ}	s_b	Constant
	TSF	1.374***	.054	-2.823	†††	1.877***	.115	-4.874
	TSM	1.049***	.008	-0.418	†††	0.976*	.009	-0.125
	TSB	0.779***	.014	0.339	NS	0.770***	.020	0.358
	FQF	1.445***	.052	-3.440	††	1.902***	.122	-5.297
HCWT	FQM	1.074***	.012	-0.801	†††	0.966**	.011	-0.372
	FQB	0.827***	.015	-0.114	NS	0.803***	.021	-0.030
	HQF	1.307***	.062	-2.833	†††	1.862***	.125	-5.101
	HQM	1.015	.019	-0.605	NS	0.988	.016	-0.483
	HQB	0.713***	.016	0.263	NS	0.727***	.021	0.180
	TSF	1.399***	.062	-2.844	†††	2.027***	.139	-5.351
	TSM	1.072***	.005	-0.453	NS	1.062***	.006	-0.407
	TSB	0.796***	.014	0.314	NS	0.839***	.016	0.128
	FQF	1.473***	.059	-3.467	†††	2.050***	.149	-5.769
TSMB	FQM	1.098***	.012	-0.835	††	1.050***	.012	-0.650
	FQB	0.845***	.015	-0.141	NS	0.875***	.017	-0.268
	HQF	1.330***	.070	-2.848	†††	2.012***	.147	-5.582
	HQM	1.039*	.017	-0.641	NS	1.076***	.014	-0.771
	HQB	0.7[illegible]***	.016	0.239	††	0.793***	.017	-0.038

‡ Regression coefficient b, standard error s_b.

* Values of b bearing this superscript are significantly ($P < 0.05$) different from 1.

† Significantly ($P < 0.05$) different in b between sexes.

grew significantly ($P < 0.05$) different from one another, with fat having the highest growth ratio (*b*) and bone having the lowest. Relative to TSMB, *b* values for fat and muscle in both sexes were significantly greater than 1 and that of bone significantly less than 1. In males, forequarter muscle (FQM) and bone (FQB) grew significantly ($P < 0.05$) faster than their respective hindquarter tissues (HQM and HQB); in females, only FQB grew significantly ($P < 0.05$) faster than HQB. In both sexes, the most variable tissue was fat.

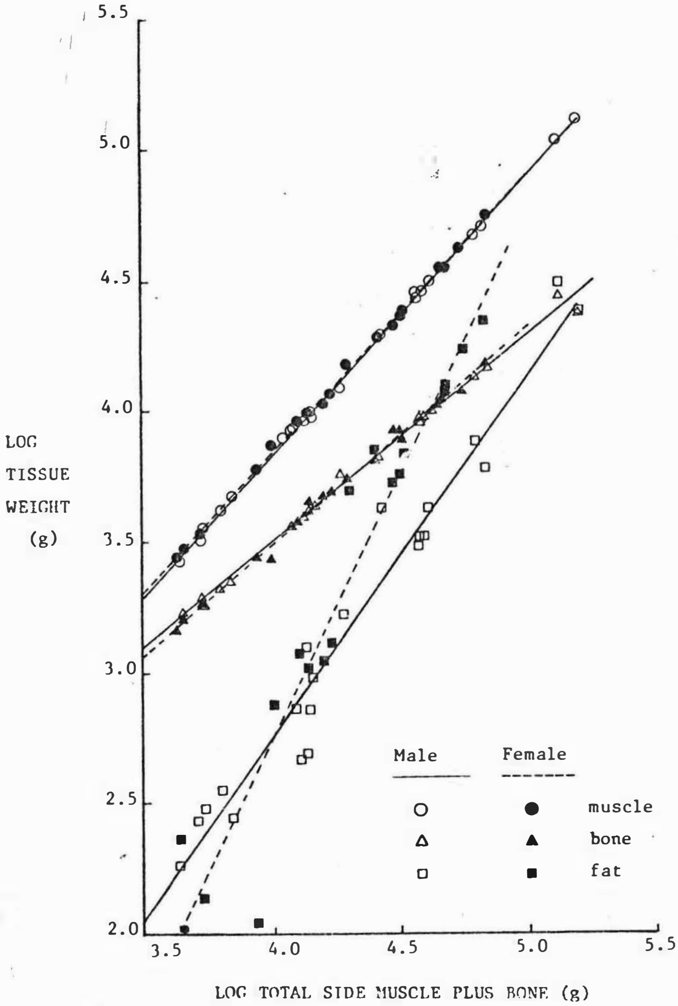


Figure 3. Allometric growth of muscle, bone and fat relative to total side muscle plus bone in 21 male and 18 female Jersey cattle, from birth to maturity.

On the basis of HCWT, significant sex differences were observed for the growth of fat (TSF, FQF, and HQF), FQM and TSM. Fat grew faster, and muscle slower, in females. When comparisons were made on TSMB, sex differences for fat growth were increased and for muscle growth decreased; significant differences were observed for fat (TSF, FQF and HQF), FQM and HQB.

3.1.1.2 Muscle:bone ratio

Using the double logarithmic regressions in Table 1, predictions were calculated at various values of TSMB for TSF, TSM, TSB and muscle:bone ratio. These together with their 95% confidence limits, are shown in Table 2. A "hypothetical" female at 140 kg TSMB was included in order to demonstrate the growth of fat to obese proportions as compared with the mature (140 kg TSMB) male. The changes in muscle:bone ratio with TSMB are plotted in Fig 4 on arithmetic coordinates.

Table 2: Predictions of total side fat (TSF), total side muscle (TSM), total side bone (TSB) and muscle:bone ratio (M:B) at various values of total side muscle plus bone (TSMB) and stages of maturity in male and female Jersey cattle, using the equations of Table 1.

	At Birth		Half Mature		Mature		Obese
TSMB (kg)	5.0	5.0	35.0	70.0	70.0	140	140
Sex	Female	Male	Female	Male	Female	Male	Female
TSF (kg)	0.14a	0.21b	7.24c	8.60c	29.5d	22.7d	120e
* Range	0.12	0.17	6.57	6.98	25.5	17.1	98.0
	0.16	0.27	7.99	10.6	34.2	30.0	148
TSM (kg)	3.33a	3.26a	26.2b	55.1c	54.8c	116d	114d
* Range	3.26	3.21	25.9	54.2	53.7	113	111
	3.40	3.37	26.6	55.9	55.9	118	117
TSB (kg)	1.71a	1.82a	8.72b	14.8c	15.6c	26.2d	27.9d
* Range	1.62	1.72	8.41	14.1	14.8	21.3	25.9
	1.80	1.91	9.04	15.5	16.5	32.2	30.1
M:B	1.95a	1.80a	3.01b	3.72c	3.51c	4.42d	4.10d
* Range	1.84	1.70	2.89	3.53	3.31	4.12	3.78
	2.07	1.90	3.13	3.91	3.72	4.73	4.44

*95% confidence limits; probability of a value outside these limits < 0.05. Values of weight within each tissue, and ratio, not followed by the same letter are outside each others confidence limits.

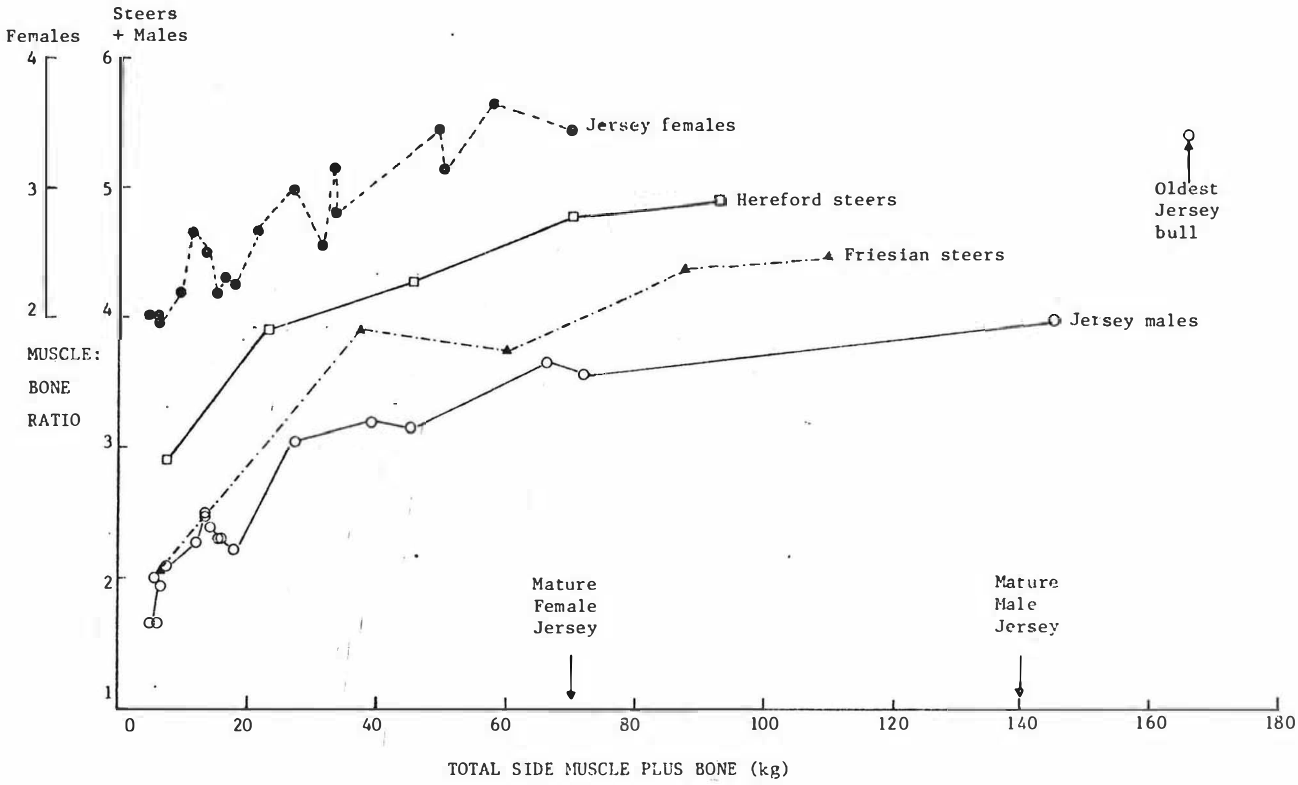


Figure 4: The change in muscle:bone ratio with total side muscle plus bone in male and female Jersey cattle (present study) and in Hereford and Friesian steers (data cited by Berg & Butterfield, 1966).

In both sexes, muscle: bone ratio increased as they grew. At the same weights of TSMB, muscle to bone ratio was similar between sexes but this was not so when compared at different stages of maturity.

3.1.2 DISCUSSION

This discussion is limited to the few experiments which compare male and female growth in one breed of cattle. Also, in experiments where anatomical dissection techniques are not used, the data are often in a form that cannot be compared to those of the present study.

3.1.2.1 Environmental conditions

The growth of the cattle used in this study occurred under normal New Zealand dairy-farming conditions. In order to minimise the effects of different environmental conditions on body composition, all animals were slaughtered in good body condition and both males and females of similar bodyweight and age group were obtained from the same source and within the same time period.

Opinions on the effects of nutrition on body composition of meat producing animals differ (Tulloh, 1964, Elsley, McDonald and Fowler, 1964; Allden, 1970; Black, 1974). Nevertheless many of the effects reported can be attributed to variation in the fat content of the body. In an allometric re-analysis of various experimental data, Tulloh (1964) noted that body composition was independent of nutritional history, although fat showed the greatest variation from the regressions. Studies on Angus (Seebeck and Tulloh, 1968a,b), and Brahman cross and Africander cross steers (Seebeck, 1973b) subjected to, respectively, a 13% and 16% bodyweight loss, at a rate of about 0.5 kg/day and from a bodyweight of about 400 kg, concluded that essentially, the loss was a reversal of the pattern during developmental growth. The nutritional study by Murray, Tulloh and Winters (1974) on Angus steers grown, without bodyweight loss, from 300 to 440 kg, at three different rates (0.8, 0.4 and 0.8 followed by 0 kg/day), also indicated no treatment effects on the carcass composition. In the context of the present study, where a wide postnatal growth range was used, differences in nutritional history, within and between sexes would have to have been even more extreme than the conditions of the above studies, in order to affect the results of a sex comparison.

3.1.2.2 Influence of fat on sex differences

In order to remove the effects of fat on the interpretation of growth data, Elsley *et al.* (1964) suggested the use of fat-free carcass weight as an independent variable. Although the present data were influenced by the independent variable chosen (Table 1), the growth of fat (TSF, FQF and HQF) and FQM, consistently showed a sex difference. This reinforces the general observations that females are fatter than males (cattle: Berg *et al.*, 1979; sheep: Fourie, Kirton and Jury, 1970; pigs: Hansson, Lundström and Malmfors, 1975; Davies, Pearson and Carr 1980) and that muscle development in the forequarter is greater in males than females (cattle: Berg and Mukhoty, 1970; Mukhoty and Berg, 1973; Bergström, 1978; sheep: Lohse, 1973; Jury, Fourie and Kirton, 1977). Fat had its greatest influence on muscle and bone growth, using HCWT as an independent variable, when its growth was highest, as for females. For example, the b values for TSM and FQM relative to HCWT in females were significantly less than 1 but became significantly greater than 1 when x was TSMB. Other trends in muscle and bone growth are also changed when the influence of fat is removed. Sex differences observed for the growth of TSM relative to HCWT, disappeared when related to TSMB while differences in b values for HQB became apparent. The significantly higher growth ratio of HQB as well as the generally higher b values for bone in females reflected the faster rate of skeletal development achieved by females.

3.1.2.3 Growth changes in tissue proportions relative to TSMB

On the basis of TSMB, males had significantly more fat at birth than females, but at heavier weights females were fatter (Table 2). Therefore on this basis of body size, females had a significantly faster rate of fattening than males (Table 1). This concurs with the findings of Berg *et al.* (1979) but differs from those of Mukhoty and Berg (1971), who reported that the rate of fattening was not significantly different between bulls, steers and heifers. Their failure to show significant differences between males and females in Hereford and Shorthorn Cross, was possibly because their experiment was restricted to a narrow range in slaughtered weights and that each sex was represented by no more than 13 animals; their standard errors for the b values for fat in each breed and sex were higher than those reported here.

Sex influences on the growth of total muscle and bone were not significant, although growth ratios for TSM and TSB relative to TSMB were higher and lower, respectively, in males than females. This was similar to the findings of Mukhoty and Berg (1971). However, their growth ratio for bone in Jersey bulls were lower and had a larger standard error (0.64 ± 0.12) than that of the present study. The median division of the vertebral column in their study would have introduced an additional error. Because their growth ratio for bone was lower, predicted muscle:bone ratio of their Jersey bulls within their range of slaughter weights, would be higher than that of the present study.

3.1.2.4 Muscle:bone ratio and maturity

Muscle:bone ratio has been used as an index of one aspect of carcass composition (Hankins, Knapp and Phillips, 1943; Carroll, Clegg and Kroger, 1964; Berg and Butterfield, 1966,1968). It has also been suggested as an index of "musculoskeletal maturity" (Davies and Kallweit, 1979). In a hypothetical calculation of muscle:bone ratio for cattle, sheep and pigs, Davies (1974a) noted similarities in muscle:bone ratio within newborn animals and within adults in the three species, and suggested that "maturity" had a greater effect on muscle:bone ratio than body size. Davies and Kallweit (1979) in their study on the German Landrace and Göttingen Miniature pigs, of differing mature body size, showed that breed differences in muscle and bone distribution were absent when comparisons were made at the same muscle:bone ratio, which represented "musculoskeletal maturity". This is valid only for a model in which the muscle:bone ratio is similar in mature animals of each group.

"Maturity" implies constancy of body composition. "Chemical maturity" is attained when water, protein and minerals approach constant proportions in the fat-free body (Moulton, 1923). Anatomically, maturity occurs when muscle and bone approach constancy in the fat-free carcass (TSMB). This can be observed as a constancy in muscle:bone ratio. While Davies and Kallweit (1979) suggested that the muscle:bone ratio is constant in a musculoskeletally mature pig, they did not present evidence that the two breeds of pigs studied achieved constant muscle:bone ratios at mature weights. Berg and Butterfield (1968) reported that the muscle:bone ratio of steers plateaus at mature weights (Fig 4). In this study, muscle:bone ratios of male and female Jersey cattle increased from birth and appeared to plateau at 140 kg and 70 kg TSMB, respectively. However, more animals between 70 to 180 kg TSMB are required to show a plateau more conclusively. In the case of the oldest bull a relatively low bone weight resulted in a very high muscle:bone ratio, perhaps due to an ageing effect. The muscle: bone ratios of female Jersey cattle were plotted on a different scale because throughout growth, there was a close overlap of their points with male Jersey cattle. This suggests that females and males follow a similar pattern of musculoskeletal development. In this study, maturity was taken to be when males achieved 140 kg and females 70 kg TSMB weights. In terms of liveweight, these weights approximate to a 640 kg male and a 400 kg female. At half maturity, both sexes would have half the TSMB weight at maturity.

When compared to the same TSMB, females and males were similar in muscle and bone weight, and hence were similar in muscle:bone ratios at various stages of growth (Table 2). However, when compared at the same maturity, significant differences at the 95% confidence limits for muscle, bone and muscle:bone ratio, but no significant difference for fat, were observed. This implies that fatness between male and female Jersey cattle can be attributed to differences in maturity. In the same way McClelland, Bonaiti and Taylor (1976) observed that maturity accounted for a large proportion (28.6%) of the total variation in dissectable fat between breeds and sexes of sheep; even though sex contributed significantly ($P < 0.001$) to this variation, it was only a relatively small contribution (3.2%).

Thus in a fat free carcass, musculoskeletal development between sexes was similar. But in the whole carcass, which includes fat (Table 1), females would have a slower rate of musculoskeletal development than males. Also, because they mature at a heavier weight they can achieve a higher muscle: bone ratio than females. In Table 2, a hypothetical "over mature" Jersey cow of 140 kg TSMB and 120 kg fat has a similar muscle:bone ratio to a bull of the same TSMB weight, but the "over maturity" is shown as a 46% proportion of carcass fat.

The concept that the muscle:bone ratio represents musculoskeletal maturity was not true for sex differences in these Jersey cattle. Instead, fat appeared to be similar in animals of similar maturity.

3.1.2.5 Breed differences in muscle:bone ratio

Fig. 4 suggests a breed difference between Hereford, Friesian and Jerseys at each level of musculoskeletal development. Studies on different cattle breeds (Mukhoty and Berg, 1971; Broadbent, Ball and Dodsworth, 1976; Berg, Anderson and Liboriussen, 1978a) imply a genetic basis for the differences observed in muscle:bone ratio. However, these studies did not consider the effects of maturity. Berg *et al.*(1974a) found no significant sire breed differences in the regressions of muscle, bone or fat on various size dimensions, but breeds differed significantly in amount of muscle, fat and bone when compared at standard weights. They also noted that breed differences in muscle:bone ratios were clearly established at birth.

All too little is known about the manner in which both sex and breed differences in cattle are expressed in terms of anatomical development. Many breed differences may in fact be sex linked.

3.1.2.6 Conclusions

The overall pattern of growth indicated that fat was the fastest growing and most variable of the three tissues; bone was the slowest growing. Forequarter tissues were faster growing than hindquarter tissues in both sexes, except for muscle in females. Fat grew faster in females than males; this accounted for much of the difference in muscle and bone between sexes, although forequarter muscle in males and hindquarter bone in females were faster growing than the corresponding tissues in the opposite sex.

Males and females followed similar patterns of growth for muscle and bone when compared at the same fat free carcass weight. Males however were able to reach higher values of muscle:bone ratio because they attained higher body weights on maturity, than females. At the same level of maturity (mature or half mature) the two sexes had similar fat content, but females had a lower muscle:bone ratio than males.

3.2 MUSCLE GROWTH

3.2.1 RESULTS

3.2.1.1 Relative growth of muscle groups and individual muscles

The allometric equations from birth to maturity for the muscle groups 1 to 10 are given in Table 3 and those for the individual muscles which make up these groups are given in Table 4. The topographical distribution of muscle groups and individual muscles according to their growth ratios are depicted for each sex in Figs 5 and 6, respectively. Of the 109 individual muscles studied, 25 muscles showed significant differences in their *b* values between sexes. The weights of these muscles for both sexes at 55.0 kg TSM weight are given in Table 5a & b. The eleven muscles which grew significantly slower in males than females (Table 5a) were found in the pelvic, spinal, sublumbar, brachial and antebrachial muscle groups. At 55.0 kg TSM, these muscles totalled about 7.4 kg in males and 8.7 kg in females, which is a sex difference of 1.4 kg. The fourteen muscles which grew significantly faster in males than females (Table 5b) were found in the brachial, extrinsic and intrinsic (neck) muscle groups; all these groups are found in the forequarter. At 55.0 kg TSM, these muscles contributed about 8.6 kg in males and 6.1 kg in females, which is a sex difference of 2.5 kg.

Table 3: Double logarithmic regressions comparing the growth of muscle group weight relative to total side muscle weight, in grammes, between 21 male and 18 female Jersey cattle, from birth to maturity.

		Male				Female		
	Muscle Group	Growth Ratio b_{ϕ}	s_b	Constant	Sex Diff.	Growth Ratio b_{ϕ}	s_b	Constant
1	PELVIC	0.965*	.016	-0.380	NS	0.994	.016	-0.485
2	CRURAL	0.825***	.018	-0.560	NS	0.851***	.011	-0.655
3	SPINAL	1.028*	.013	-1.128	NS	1.059***	.012	-1.235
4	SUBLUMBAR	0.919**	.027	-1.219	††	1.042	.022	-1.674
5	ABDOMINAL	1.123***	.015	-1.649	NS	1.145***	.025	-1.697
6	BRACHIAL	0.987	.010	-0.890	NS	0.978	.013	-0.857
7	ANTEBRACHIAL	0.806***	.012	-0.713	NS	0.844***	.015	-0.890
8	EXTRINSIC	1.062***	.014	-1.076	†	1.016	.011	-0.925
9	INTRINSIC (NECK)	1.077*	.028	-1.302	††	0.956	.024	-0.858
10	THORACIC	0.925**	.023	-0.957	†	1.010	.024	-1.283

ϕ Regression coefficient *b*, standard error s_b

* Values of *b* bearing this superscript are significantly ($P < 0.05$) different from 1.

† Significantly ($P < 0.05$) different in *b* between sexes

Table 4: Double logarithmic regressions comparing the growth of individual muscle weight relative to total side muscle weight, in grammes, between 21 male and 18 female Jersey cattle, from birth to maturity.

	Male				Female		
Individual muscle	Growth Ratio b_{ϕ}	s_b	Constant	Sex Diff.	Growth Ratio b_{ϕ}	s_b	Constant
1 PELVIC							
Tensor fasciae latae	1.076***	.023	-2.229	NS	1.144***	.027	-2.475
Biceps femoris	1.005	.017	-1.225	NS	1.005	.020	-1.206
Semitendinosus	1.047*	.019	-1.850	NS	1.032	.024	-1.794
Gluteus medius	1.022	.018	-1.592	†	1.073***	.017	-1.776
Gluteus accessorius	0.987	.027	-2.511	NS	1.070	.043	-2.797
Gluteus profundus	0.937*	.029	-2.127	††	1.069	.029	-2.661
Gemelli	0.771***	.055	-2.110	NS	0.804**	.054	-2.211
Sartorius	0.807***	.029	-1.622	NS	0.893	.053	-1.984
Gracilis	0.936**	.020	-1.648	NS	0.962	.046	-1.767
Pectineus	0.919*	.029	-1.895	NS	0.943	.028	-1.960
Semimembranosus	0.950	.027	-1.093	NS	0.956	.029	-1.098
Quadratus femoris	1.030	.074	-3.139	NS	0.928	.057	-2.825
Adductor	0.965	.039	-1.617	NS	0.995	.035	-1.710
Rectus femoris	0.904***	.020	-1.269	††	0.997	.016	-1.636
Vastus lateralis	0.895***	.022	-1.171	NS	0.949	.024	-1.396
Vastus intermedius	0.890*	.045	-1.682	NS	0.821	.036	-1.312
Vastus medialis	0.794***	.033	-1.248	††	0.930	.035	-1.797
Obturatorius externus (et internus)	0.955	.026	-2.018	NS	0.987	.034	-2.107
2 CRURAL							
Gastrocnemius	0.855***	.022	-1.077	NS	0.863***	.017	-1.093
Flexor digitorum superficialis	0.730***	.037	-1.196	NS	0.819***	.023	-1.518
Peroneus tertius et extensor digitorum longus	0.819***	.019	-1.398	NS	0.839***	.022	-1.470
Tibialis cranialis	0.715***	.025	-1.665	NS	0.682***	.064	-1.570
Peroneus longus	0.769***	.030	-1.971	NS	0.738***	.050	-1.874
Extensor digitorum lateralis	0.841***	.027	-1.952	NS	0.890*	.038	-2.168
Popliteus	0.841***	.039	-1.844	NS	0.803***	.058	-1.635
Flexor digitorum profundus	0.827***	.026	-1.281	NS	0.904**	.032	-1.583
3 SPINAL							
Longissimus thoracis	1.025	.019	-1.652	NS	1.015	.020	-1.603
Longissimus lumborum	1.061	.034	-1.795	NS	1.141***	.020	-2.076
Longissimus (total)	1.042	.021	-1.417	NS	1.082***	.016	-1.555
Ilicostalis thoracis	1.034	.028	-2.455	NS	0.984	.038	-2.286
Iliocostalis lumborum	0.714**	.077	-1.798	NS	0.904	.099	-2.659
Iliocostalis (total)	0.977	.034	-2.127	NS	0.964	.038	-2.124
Multifidis thoracis	0.968	.066	-2.234	NS	1.053	.039	-2.511
Multifidis lumborum	0.963	.031	-2.210	††	1.139*	.051	-2.887
Multifidis (total)	0.964	.037	-1.906	†	1.089*	.033	-2.366
Spinalis cervicis et thoracis	1.066**	.022	-2.013	NS	1.009	.028	-1.795
Sacrocaudalis ventralis	1.001	.070	-3.282	NS	0.926	.065	-2.960
Sacrocaudalis dorsalis	0.953	.054	-2.515	NS	1.011	.048	-2.662
4 SUBLUMBAR							
Psoas minor	0.877*	.045	-1.987	NS	0.972	.046	-2.348
Iliopsoas	0.922**	.026	-1.316	††	1.042	.022	-1.760
Quadratus lumborum	0.950	.062	-2.533	NS	1.141	.084	-3.248
5 ABDOMINAL							
Cutaneus trunci	1.162***	.027	-2.546	NS	1.133***	.028	-2.386
Rectus abdominis	1.075***	.019	-2.067	NS	1.040	.037	-1.883
Obliquus externus abdominis	1.082**	.028	-2.118	NS	1.172***	.041	-2.481
Obliquus internus abdominis	1.215***	.051	-2.780	NS	1.195***	.036	-2.604
Transversus abdominis	1.128***	.027	-2.465	NS	1.207***	.042	-2.744

ϕ Regression coefficient b, standard error s_b.

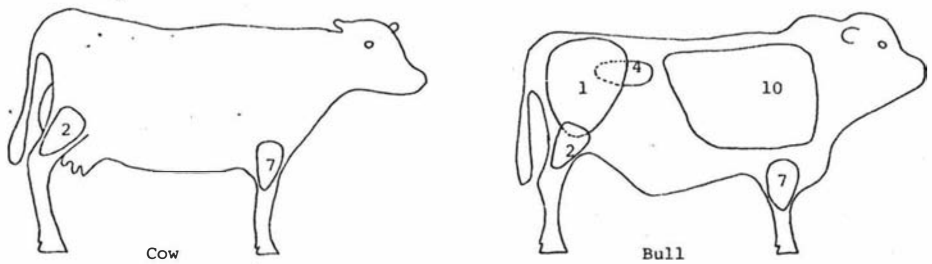
* Values of b bearing this superscript are significantly ($P < 0.05$) different from 1.

† Significantly ($P < 0.05$) different in b between sexes.

Table 4 continued

Individual muscle	Male Growth Ratio b_ϕ	s_b	Constant	Sex Diff.	Female Growth Ratio b_ϕ	s_b	Constant
6 BRACHIAL							
Deltoideus	1.036	.023	-2.467	†	0.954	.024	-2.173
Infraspinatus	0.997	.012	-1.718	†	1.056**	.019	-1.940
Supraspinatus	0.933***	.015	-1.537	NS	0.929**	.024	-1.487
Coracobrachialis	0.986	.038	-2.834	NS	0.929	.076	-2.584
Subscapularis	1.087**	.030	-2.316	NS	1.054	.028	-2.193
Teres major	0.975	.024	-2.235	NS	0.984	.032	-2.300
Biceps brachii	0.933**	.020	-1.928	†	0.999	.020	-2.185
Teres minor	0.934	.049	-2.388	NS	0.926	.058	-2.389
Tensor fasciae antebrachii	1.008	.046	-2.868	NS	0.935	.033	-2.588
Triceps brachii: Caput laterale	0.883***	.021	-1.674	NS	0.927**	.021	-1.840
Caput longum	1.040*	.015	-1.674	†	0.984	.015	-1.461
Caput mediale	0.756***	.045	-1.935	NS	0.707***	.044	-1.683
Brachialis	0.839***	.013	-1.604	NS	0.873***	.018	-1.755
Anconeus	0.821**	.061	-2.164	NS	0.823**	.045	-2.224
7 ANTEBRACHIAL							
Extensor carpi radialis	0.852***	.020	-1.461	NS	0.824***	.014	-1.379
Extensor digitorum lateralis	0.779***	.032	-1.893	NS	0.830***	.032	-2.157
Extensor digitorum communis	0.826***	.040	-1.910	NS	0.783***	.026	-1.543
Abductor pollicis longus	0.675**	.094	-2.249	NS	0.735***	.055	-2.4[illegible]
Ulnaris lateralis	0.825***	.016	-1.749	NS	0.951	.065	-2.310
Flexor carpi ulnaris	0.776***	.036	-1.877	†	0.877***	.026	-2.305
Flexor carpi radialis	0.723***	.028	-1.743	NS	0.705***	.031	-1.699
Flexor digitorum superficialis	0.755***	.033	-1.375	†	0.868**	.038	-1.816
Flexor digitorum profundus:							
Caput ulnare	0.890***	.027	-2.428	NS	0.926	.045	-2.595
Caput radiale	0.673***	.064	-2.246	†	0.936	.083	-3.335
Caput humerale	0.779***	.030	-1.317	NS	0.827**	.034	-1.521
8 EXTRINSIC							
Trapezius	1.106*	.041	-2.398	NS	1.040	.026	-2.197
Brachiocephalicus	0.994	.038	-1.799	NS	0.928*	.025	-1.598
Omotransversarius	1.115*	.047	-2.794	†	0.951	.049	-2.183
Rhomboideus	1.106**	.035	-2.298	††	0.910*	.036	-1.632
Latissimus doris	1.068**	.020	-2.002	NS	1.049*	.019	-1.947
Serratus ventralis cervicis et thoracis	1.101***	.013	-1.824	NS	1.122***	.014	-1.884
Pectoralis profundus	1.010	.019	-1.510	†	0.958**	.013	-1.329
Pectoralis superficialis	1.038	.032	-2.015	NS	0.970	.033	-1.812
9 INTRINSIC (NECK)							
Sternomandibularis	1.105*	.047	-2.760	††	0.837***	.038	-1.771
Sternomastoideus	0.975	.045	-2.159	NS	0.965	.069	-2.156
Sternothyrohyoideus	0.957	.067	-2.505	NS	0.932	.089	-2.431
Omohyoideus	1.096	.121	-3.805	NS	1.059	.195	-3.868
Splenius capitis et cervicis	1.279***	.058	-3.203	††	0.935	.037	-2.033
Longissimus cervicis	1.102*	.048	-2.739	NS	1.000	.050	-2.354
Longissimus capitis	1.123*	.053	-2.949	††	0.867**	.035	-2.066
Longissimus atlantis	1.274**	.090	-4.216	†	0.837	.146	-2.626
Semispinalis capitis, cervicis et thoracis	1.126**	.039	-2.203	††	0.958	.026	-1.581
Scalenus dorsalis	1.209**	.061	-3.401	††	0.936	.075	-2.466
Scalenus ventralis	1.028	.038	-2.446	NS	0.961	.038	-2.183
Intertransversarii cervicis	0.965	.044	-2.104	NS	1.046	.067	-2.440
Intertransversarius longus	1.088	.042	-2.838	NS	1.014	.066	-2.600
Longus capitis	1.032	.053	-2.605	NS	0.857	.069	-2.021
Longus colli	1.098*	.043	-2.525	NS	1.096*	.038	-2.490
Obliquus capitis caudalis	1.045	.022	-2.555	†	0.960	.027	-2.201
Obliquus capitis cranialis	0.767***	.041	-1.908	NS	0.737***	.057	-1.742
Rectus capitis dorsalis major	0.941	.047	-2.543	NS	0.907*	.039	-2.398
Rectus capitis dorsalis minor	0.633	.106	-1.940	NS	0.660*	.120	-2.124
Rectus capitis ventralis	0.948	.096	-3.034	NS	1.097	.091	-3.659
Rectus capitis lateralis	0.984	.088	-2.962	†	0.711**	.086	-1.735
Multifidis cervicis	1.008	.043	-2.478	†	0.818*	.081	-1.716
10 THORACIC							
Interspinales	0.769***	.055	-1.673	NS	0.843**	.041	-1.951
Rectus thoracis	1.030	.024	-3.010	NS	1.057	.045	-3.137
Serratus dorsalis cranialis	0.936	.069	-2.624	NS	0.973	.091	-3.004
Serratus dorsalis caudalis	0.996	.069	-2.951	NS	1.148*	.063	-3.568
Retractor costae	0.994	.064	-3.086	NS	1.143	.122	-3.766
Intercostales	0.959*	.015	-1.347	NS	0.949	.038	-1.287
Transversus thoracis	0.963	.035	-2.542	NS	1.078	.049	-2.966
Diaphragma	1.014	.028	-1.992	NS	1.086**	.027	-2.244

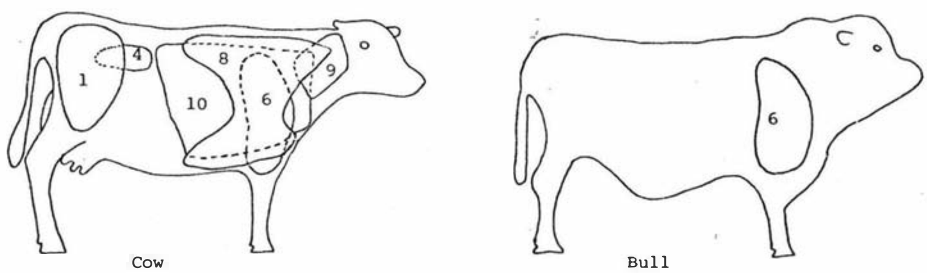
b significantly (P < 0.05) less than 1



Cow — 2 muscle groups

Bull — 5 muscle groups

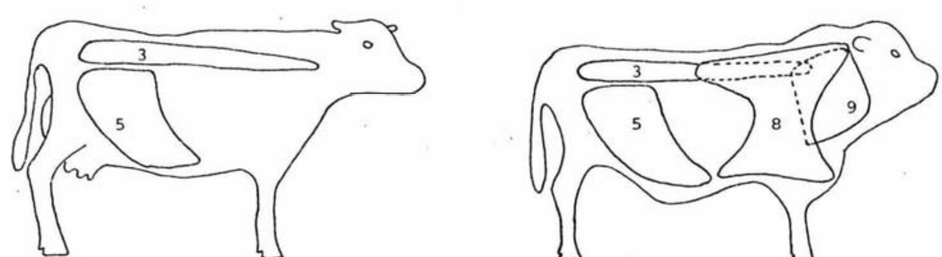
b not significantly (P < 0.05) different from 1



Cow — 6 muscle groups

Bull — 1 muscle group

b significantly (P < 0.05) greater than 1



Cow — 2 muscle groups

Bull — 4 muscle groups

Figure 5: Differences in muscle weight distribution between the cow and bull as observed in the growth ratios *b* of the muscle groups, given in Table 3.

1 = Pelvic 2 = Crural 3 = Spinal 4 = Sublumbar 5 = Abdominal
6 = Brachial 7 = Antebrachial 8 = Extrinsic 9 = Intrinsic (neck)
10 = Thoracic

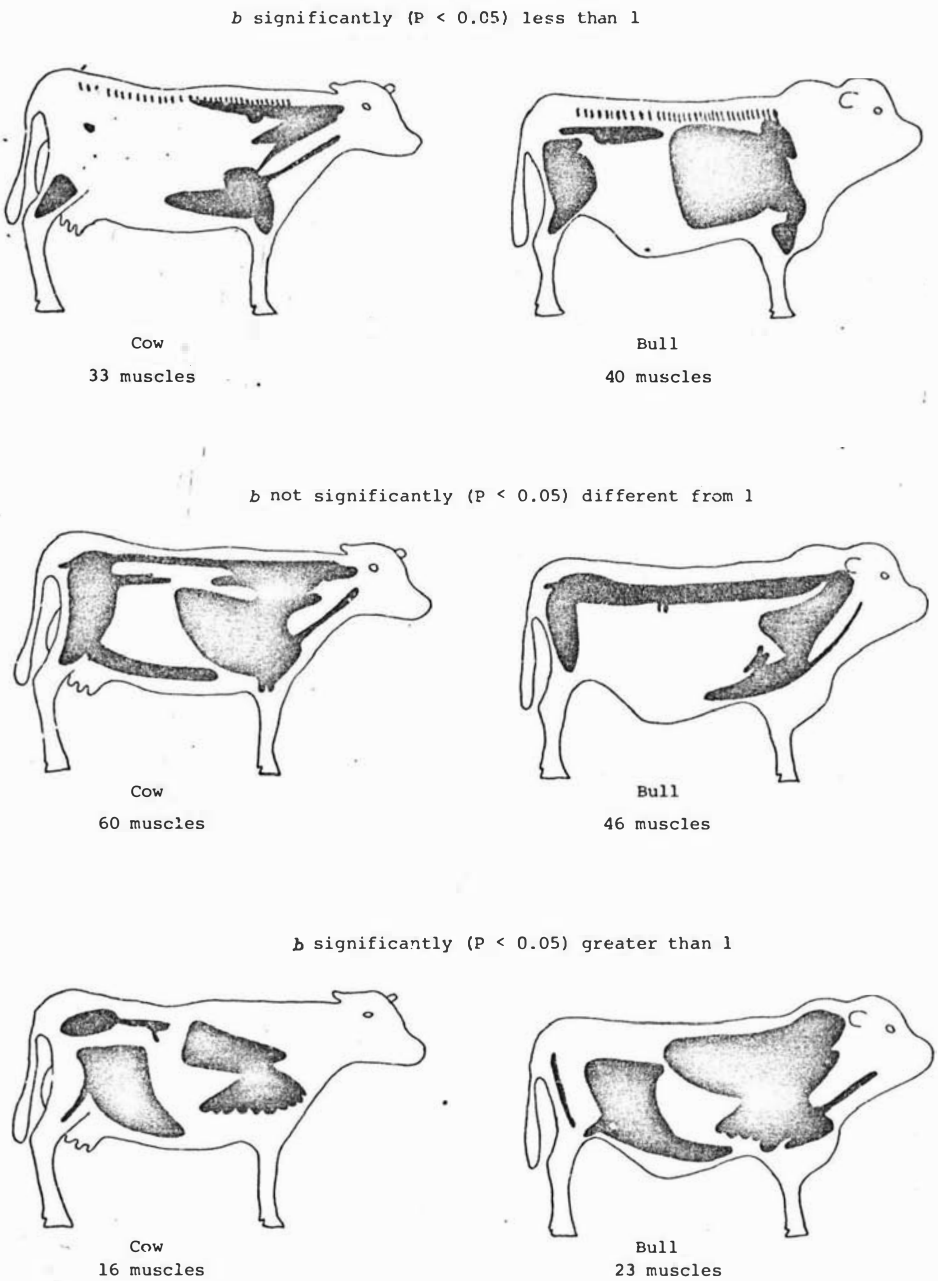


Figure 6: Differences in muscle weight distribution between the cow and bull as observed from the allocation of individual muscles according to their growth ratio *b* (Table 4).
The number of muscles within each of the three allocations is indicated.

These results show that the forequarter, especially the neck, is better developed in males than females. There is a marked effect (over 50% increase) in six muscles, all in the neck. Otherwise, muscle distribution is not greatly different between the two sexes.

Table 5: Weights of muscle in grammes for male and female Jersey cattle, at 55.0 kg total side muscle (TSM), as calculated from the regressions given in Table 4.

(a) Muscles whose *b* values are significantly lower in males than females

Muscle group	Muscle	Male	Female	Sex ratio*
Pelvic	Gluteus medius	1788	2042	0.88
	Gluteus profundus	206	255	0.81
	Rectus femoris	1038	1230	0.84
	Vastus lateralis	1178	1266	0.93
Spinal	Multifidis	461	625	0.74
Sublumbar	Iliopsoas	1133	1510	0.75
Brachial	Infraspinatus	1018	1163	0.88
	Biceps brachii	312	355	0.88
Antebrachial	Flexor carpi ulnaris	63.3	71.1	0.89
	Flexor digitorum superficialis	160	199	0.80
	Flexor digitorum profundus: Caput radiale	5.8	12.6	0.46
				Difference
	Total	7363	8728	1365
	Total expressed as % TSM	13.4	15.9	2.5
	Total expressed as % HCW†	8.9	9.0	0.1

(b) Muscles whose *b* values are significantly higher in males than females

Muscle group	Muscle	Male	Female	Sex ratio*
Brachial	Deltoideus	278	223	1.24
	Triceps brachii: Caput longum	1801	1597	1.13
Extrinsic	Omotransversarius	310	211	1.47
	Rhomboideus	880	480	1.83
	Pectoralis profundus	1894	1629	1.16
Intrinsic (neck)	Sternomandibularis	300	157	1.91
	Splenius	724	251	2.89
	Longissimus capitis	237	111	2.14
	Longissimus atlantis	66.5	21.9	3.04
	Semispinalis	1362	912	1.49
	Scalenus dorsalis	214	93.5	2.29
	Obliquus capitis caudalis	250	224	1.12
	Rectus capitis lateralis	50.4	43.2	1.17
	Multifidis cervicis	200	145	1.38
				Difference
	Total	8566	6098	2467
	Total expressed as % TSM	15.6	11.1	4.5
	Total expressed as % HCWT†	10.4	6.3	4.1

* Weight of muscle in male/Weight of muscle in female

† Half carcass weight (HCWT), as estimated from the regressions in Table 1, is 82.6 kg for males and 96.5 kg for females.

3.2.1.2. Relative growth of the testis

A break in the allometric growth of the testis relative to total side muscle (TSM) is observed in Fig. 7. Two regressions, one including the first eight and the other, the next eleven males, significantly ($P < 0.01$) reduced the residual mean squares of the single regression for these nineteen animals. In the first phase the testis grew at a low growth ratio of 0.658 (Table 6) and in the second phase, assumed a higher growth ratio of 1.816. The two heaviest and oldest bulls, aged 5 and 7 years, were omitted in the calculations of the second phase regression because testicular growth in these mature bulls appeared to have assumed another phase, lower in growth rate than that in phase 2 (Figs. 7 & 20). The heaviest calf in phase 1 had a liveweight of about 50 kg and a TSM of 9.2 kg (Fig. 20, Appendix 4). The lightest calf in phase 2 had a liveweight of about 60 kg and a TSM of 9.7 kg. The position of the break in allometry was similar when other independent variables such as liveweight (Fig. 20), empty body weight, half carcass weight, total side muscle plus bone and total side bone were used instead of TSM.

3.2.1.3. Relative growth of *mm. rhomboideus, splenius* and *longissimus capitis*

The monophasic equations of *mm. rhomboideus, splenius* and *longissimus capitis* in Table 4, indicate that these muscles are faster growing in males than females. Figs. 8, 9 & 10 show that the allometric growth of each of these neck muscles is in two phases. Based on the evidence on the position at which the break in the relative growth of the testis occurred, two regressions were fitted, one to the first eight animals and another to the next thirteen animals. The two regressions were significantly ($P < 0.005$) better than a single regression in representing the relative growth of these muscles in males. On the other hand, the allometric growth of these muscles in females did not show obvious breaks and was each adequately described by a single regression; two regressions did not significantly ($P > 0.05$) reduce the residual mean squares of the single regression of each muscle.

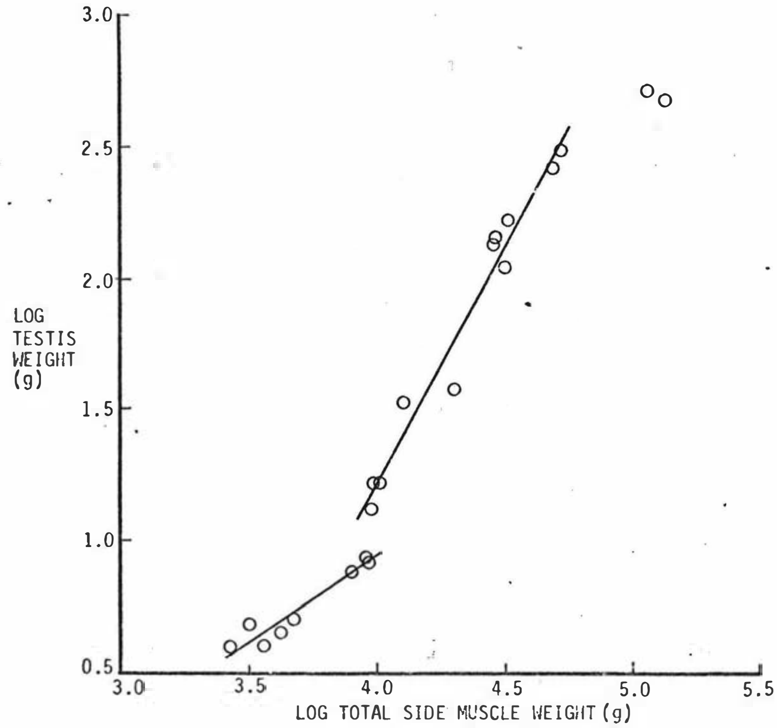


Figure 7: Allometric growth of mean testis weight relative to total side muscle weight in male Jersey cattle, from birth to maturity. The two heaviest bulls, aged 5 and 7 years, have been omitted from the second phase regression.

Table 6: Double logarithmic regressions of the growth of testis relative to total side muscle (TSM), in two phases.

x = TSM (g) y = weight of testis (g)

	Growth Ratio bΦ	s_b	Constant
Phase 1 #	0.659a**	.079	-4.757
Phase 2 #	1.816b***	.112	-6.041

Φ Regression coefficient b, standard error s_b.

\# Phase 1 includes the first 8 males; phase 2 includes the next 11 males.

* Values of b bearing this superscript are significantly ($P < 0.05$) different from 1. Values of b in phase 1 and phase 2 not followed by the same letter are significantly ($P < 0.001$) different from one another.

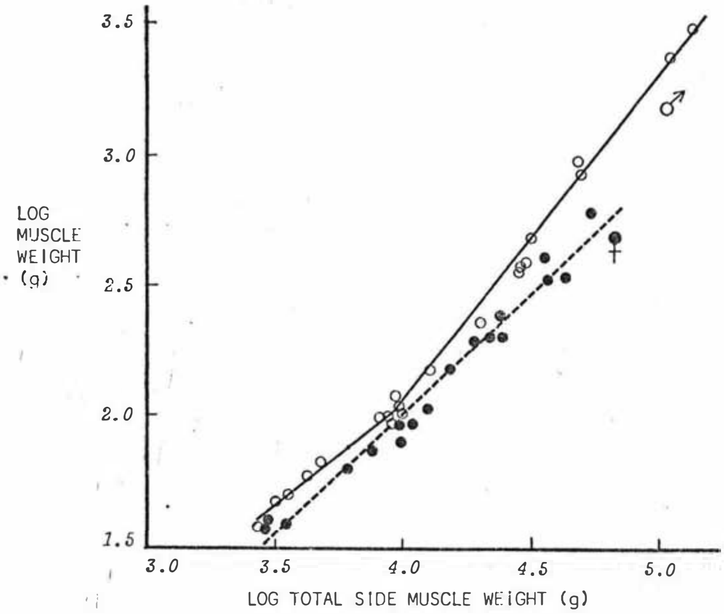


Figure 8: Allometric growth of *m. rhomboideus* relative to total side muscle weight in male (o) and female (●) Jersey cattle, from birth to maturity.

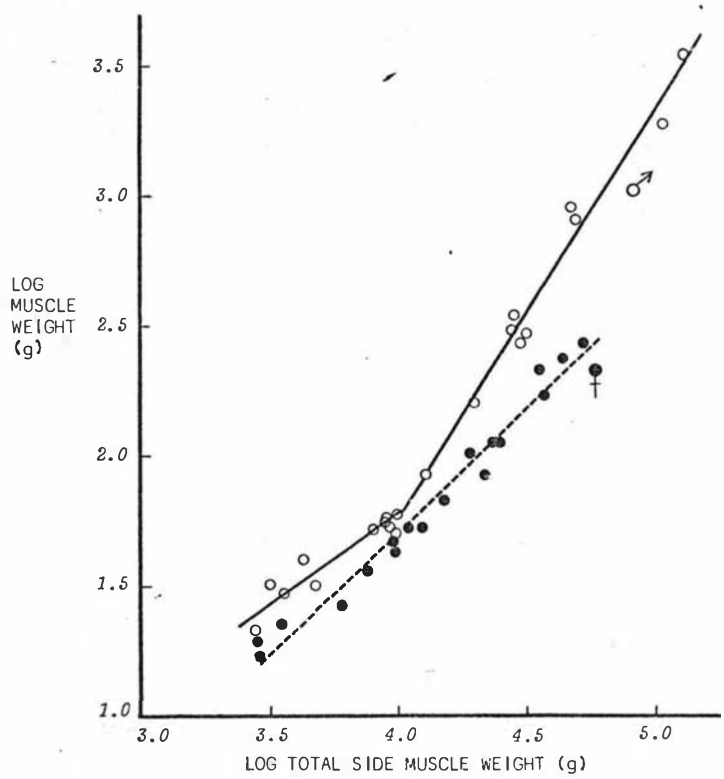


Figure 9: Allometric growth of *m. splenius* relative to total side muscle weight in male (O) and female (●) Jersey cattle, from birth to maturity.

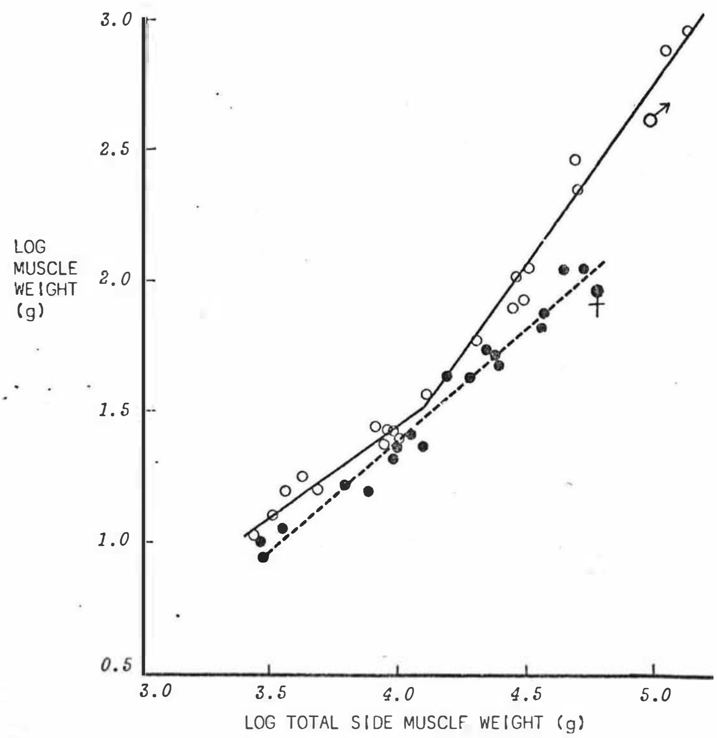


Figure 10: Allometric growth of *m. longissimus capitis* relative to total side muscle in male (O) and female (●) Jersey cattle, from birth to maturity.

The allometric equations of these muscles in males are given in Table 7. The growth of the three muscles was significantly faster in phase 2 than in phase 1, with *m. splenius* showing the greatest and *m. rhomboideus* the smallest change in allometry.

Table 7: Double logarithmic regressions of the growth of *mm. rhomboideus, longissimus capitis* and *splenius* relative to total side muscle (TSM) in two phases, for 21 male Jersey cattle, and compared to the single regression of each of the muscles, in 18 females.

x = TSM (g) y = weight of muscle (g)

	Males					Females		
Muscle	Phase#	Growth Ratio bΦ	s_b	Constant	Sex Diff.	Growth Ratio bΦ	s_b	Constant
RHOMBOIDEUS	1	0.786a**	.051	-1.080	NS	0.910*	.036	-1.632
	2	1.262b***	.033	-3.008	+++			
LONGISSIMUS CAPITIS	1	0.702a*	.082	-1.339	NS	0.867**	.035	-2.066
	2	1.372b***	.052	-4.092	+++			
SPLENIUS	1	0.712a*	.095	-1.053	+	0.935	.037	-2.033
	2	1.540b***	.049	-4.395	+++			

Φ Regression coefficient b, standard error s_b.

\# Phase 1 includes the first 8 males; phase 2 includes the other 13 males.

* Values of b bearing this superscript are significantly ($P < 0.05$) different from 1. Values of b in phase 1 and phase 2 not followed by the same letter are significantly ($P < 0.001$) different from one another.

\+ Significantly ($P < 0.05$) different in b between sexes.

3.2.1.4 Relative growth of *mm. longissimus* and *semitendinosus*

The allometric equations for *mm. longissimus* and *semitendinosus* in Table 4 and Figs. 11 & 12, show no significant sex difference in the growth of these muscles. In both sexes, breaks in allometry were not evident and a single regression adequately described the growth of each muscle; two regressions did not significantly ($P > 0.05$) improve the relationship.

3.2.1.5 Growth changes in measurements of muscle area relative to weight of muscle; estimation of fibre number

Table 8 gives the allometric equations for the change in various measurements of muscle area relative to weight of muscle. The areas are all transverse sectional area:

(a) whole muscle area (WMA) and mean fibre area (MFA),
(b) total area occupied by myosin ATPase high fibres (TAH) and mean myosin ATPase high fibre area (MAH), and
(c) total area occupied by myosin ATPase low fibres (TAL) and mean myosin ATPase low fibre area (MAL).

The change in WMA and MFA relative to weight of muscle for *mm. rhomboideus, splenius, longissimus capitis, longissimus* and *semitendinosus* is shown in Figs. 13 to 17. Predictions of each of the above mentioned areas allowed estimation of total fibre number (N), number of myosin ATPase high fibres (NAH) and number of myosin ATPase low fibres (NAL) at two muscle weights, representing two stages of growth, as shown in Table 9. Comparisons between sexes, using 95% confidence limits, were made at the same muscle weight, for each of the values.

Sex differences in muscle growth were exemplified by the neck muscles, *mm. rhomboideus, splenius* and *longissimus capitis*. When contrasted with the growth of *mm. longissimus* and *semitendinosus*, which appeared to be similar between sexes, it is possible to make some observations on the mechanism of muscle growth, upon which differences and similarities of muscle growth between sexes can be based. Both sexes

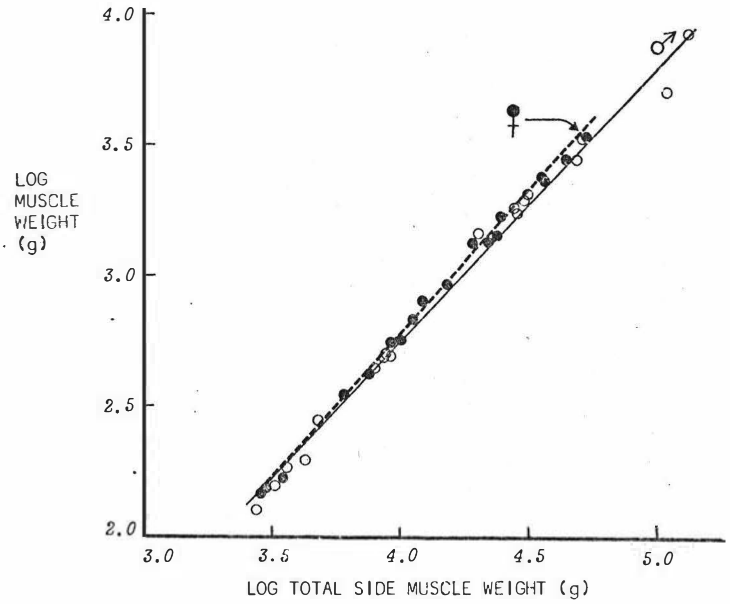


Figure 11: Allometric growth of *m. longissimus* relative to total side muscle weight in male (○) and female (●) Jersey cattle, from birth to maturity.

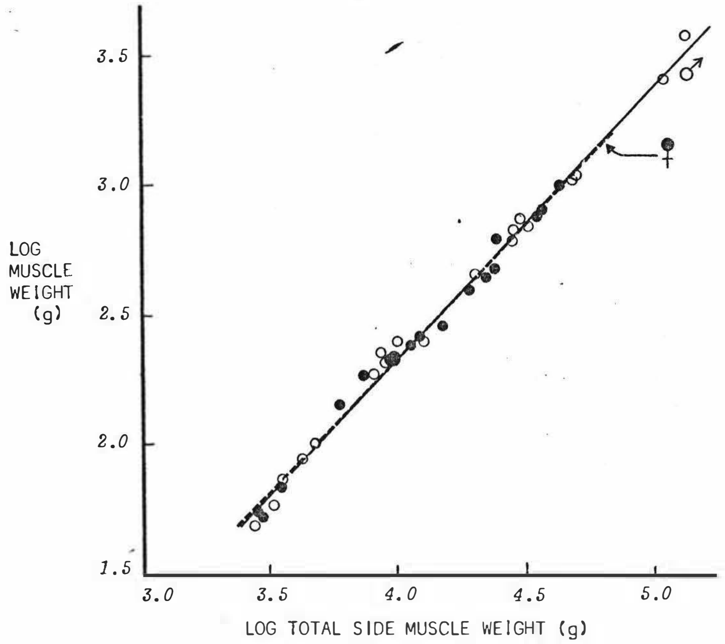


Figure 12: Allometric growth of *m. semitendinosus* relative to total side muscle weight in male (○) and female (●) Jersey cattle, from birth to maturity.

Table 8: Double logarithmic regressions comparing the changes of various measurements of transverse sectional muscle area (in μm^2) relative to the weight of the respective muscle (in g), between 21 male and 18 female Jersey cattle, from birth to maturity. *x* is the weight of muscle and *y* is one of the following: (a) whole muscle area (WMA) and mean fibre area (MFA); (b) total area occupied by myosin ATPase high fibres (TAH) and mean myosin ATPase high fibre area (MAH); and (c) total area occupied by myosin ATPase low fibres (TAL) and mean myosin ATPase low fibre area (MAL).

			Male				Female		
Muscle		*y*	Growth Ratio b_ϕ	s_b	Constant	Sex Diff.	Growth Ratio b_ϕ	s_b	Constant
Rhomboideus	(a)	WMA	0.793***	.028	7.019	†	0.645	.054	7.250
		MFA	0.807***	.036	1.220	NS	0.714	.048	1.614
	(b)	TAH	0.852***	.039	6.693	NS	0.735	.059	6.854
		MAH	0.878***	.042	1.055	NS	0.787	.058	1.436
	(c)	TAL	0.674	.043	6.827	†	0.488*	.073	7.147
		MAL	0.669	.042	1.525	NS	0.584	.049	1.923
Splenius	(a)	WMA	0.797***	.027	7.251	††	0.636	.041	7.473
		MFA	0.821**	.041	1.264	†	0.670	.049	1.772
	(b)	TAH	0.874***	.030	6.858	†	0.749	.052	6.984
		MAH	0.895***	.043	1.079	†	0.731	.059	1.616
	(c)	TAL	0.670	.034	7.119	†	0.505**	.055	7.383
		MAL	0.700	.040	1.554	NS	0.614	.044	1.924
Longissimus capitis	(a)	WMA	0.838***	.039	7.427	†	0.664	.063	7.634
		MFA	0.824**	.054	1.467	NS	0.751	.079	1.763
	(b)	TAH	0.874***	.050	7.132	††	0.547	.081	7.507
		MAH	0.851*	.065	1.371	NS	0.663	.087	1.795
	(c)	TAL	0.754	.056	7.167	NS	0.783	.074	7.146
		MAL	0.775*	.049	1.620	NS	0.819	.081	1.784
Longissimus	(a)	WMA	0.648	.025	7.589	NS	0.664	.034	7.517
		MFA	0.691	.042	1.179	NS	0.577*	.038	1.580
	(b)	TAH	0.644	.029	7.521	NS	0.658	.036	7.474
		MAH	0.697	.044	1.184	†	0.570*	.041	1.628
	(c)	TAL	0.700	.067	6.655	NS	0.710	.070	6.487
		MAL	0.672	.052	1.119	NS	0.633	.044	1.265
Semitendinosus	(a)	WMA	0.707*	.018	7.527	NS	0.686	.027	7.542
		MFA	0.762	.057	1.406	†	0.594	.051	1.862
	(b)	TAH	0.736**	.021	7.391	NS	0.735*	.028	7.347
		MAH	0.769	.058	1.400	†	0.602	.052	1.859
	(c)	TAL	0.544	.108	6.984	NS	0.438	.150	7.275
		MAL	0.707	.059	1.453	†	0.517*	.053	1.960

ϕ Regression coefficient *b*, standard error s_b.

* Values marked with an asterisk are significantly ($P < 0.05$) different from 0.667 and therefore indicate disproportionality.

† Significantly ($P < 0.05$) different in *b* between sexes.

share the following common features of muscle growth, from birth to maturity:

1. Total number of muscle fibres remains constant. This could be inferred from the non-significant difference ($P > 0.05$) in *b* values for the regressions of WMA and of MFA relative to muscle weight (Table 8), within each sex and each muscle. Table 9 also shows no significant change in N at two stages of growth.
2. Muscles grow by increasing muscle fibre size (MFA). Both myosin ATPase high (AH) and myosin ATPase low (AL) fibres increase in size.
3. The total number of fibres of each type remains relatively constant. This suggests that a change in myosin ATPase characteristics did not occur.

These basic features of postnatal muscle growth in cattle, delimit the ways by which sex differences in muscle growth can be achieved. Thus, differences are effected in the following ways:

1. A sex difference in the number of muscle fibres is already established at birth. Males have more fibres than females for all the five muscles. A significant difference in N, amounting to males having about twice the number of fibres than in females, is observed throughout the growth of the neck muscles. *M. longissimus* is not significantly different in N between sexes at any stage. In the case of *m. semitendinosus* the initial value of N is significantly greater in males than females, but differences are not observed at a later stage of growth.
2. The increase in muscle fibre size is faster in males than in females, and significantly so for *mm. splenius* and *semitendinosus*. In males, the *b* values of the regression of MFA relative to the weight of each of the neck muscles was significantly ($P < 0.001$) greater than 0.667, but not significantly ($P > 0.05$) different from 0.667 in females (Table 8). A value of 0.667 indicates proportionality. Comparisons between males and females of predicted MFA values at the same weight of muscle for all muscles indicated that males started with significantly smaller fibres which, however, grew to similar fibre size at heavier weights. This

increase in fibre size was greater for the neck muscles than for the other two muscles

However, the increase in fibre size in all three neck muscles of males could not entirely account for the significantly faster growth of WMA in males than in females, because only *m. splenius* showed a significant sex difference in the rate of growth of MFA. In fact, at the heavier weight, the predicted MFA values for *m. rhomboideus* was significantly less in males than females and similar for the other two neck muscles. Hence, a significantly greater number of muscle fibres results in bigger neck muscles of bulls. For similar reasons, although MFA of *m. semitendinosus* increased significantly faster in males than females, it did not result in a significant difference in muscle size between sexes. In the case of *m. longissimus*, both the rate of increase of MFA and the number of fibres are not significantly different between sexes. Hence this muscle does not differ in size between sexes.

3. Males have significantly more NAH as well as NAL than females in all the neck muscles.

In males, AH fibres contribute more than AL fibres to the increase in size of the neck muscles. The *b* values for TAH are greater than for TAL and significantly so for *mm. rhomboideus* ($P < 0.01$) and *splenius* ($P < 0.001$). This is because (i) there are significantly more NAH than NAL (Table 9), and (ii) the rate of increase in size is faster in the AH fibres than the AL fibres in each muscle; the *b* values for MAH are higher than for MAL and significantly ($P < 0.01$) so for *mm. rhomboideus* and *splenius*.

In females, the growth pattern of histochemical fibre types is less consistent than as seen for the three neck muscles in males. The contribution by AH fibres to the growth of neck muscles is not as much or as evident as in males. The *b* values for TAH and MAH are significantly greater than 0.667 in males but not so in females. Although in females the growth of *m. rhomboideus* can be attributed more to the significantly ($P < 0.05$) faster rate of increase in size and greater number of AH than AL fibres, these two reasons cannot be given for the growth of the other two neck muscles. For *m. splenius*, the increase in size and the number of AH fibres, although faster and greater, respectively, than AL fibres, are not significantly ($P > 0.05$) different. Overall, the growth of *mm. rhomboideus* and *splenius* is faster in TAH than TAL; the *b* values for TAH are significantly ($P < 0.05$) higher than for TAL in both muscles. In contrast, the growth of *m. longissimus capitis* is not due to AH more than AL fibres. In fact, the rate of increase of TAH is significantly ($P < 0.05$) slower than TAL. This is because AH fibres grow slower than AL fibres. Thus, although AH fibres are in greater numbers than AL fibres, their final contribution to the total area of the muscle is about 43%, as opposed to 57% by AL fibres.

In both sexes, AH fibres occur in greater numbers than AL fibres in both *mm. longissimus* and *semitendinosus*. In these two muscles, there are no significant differences between sexes in the number of AH and AL fibres. AH fibres in both muscles and AL fibres in *m. semitendinosus* grow significantly faster in males than females.

Photomicrographs of the transverse sections of the five muscles of both sexes, stained for myosin ATPase, are shown in Figs. 18 & 19. Subjectively, the histochemical configuration at birth is similar between sexes (Fig. 18) but as the animal grows, some differences between sexes become discernible in the neck muscles of adults (Fig. 19). AH fibres in the neck muscles appear to occupy a larger area of the muscle than AL fibres in males, than is seen in females. AH fibres also appear larger in males than females. These sex differences in histochemical fibre configuration are most evident in *m. longissimus capitis*.

3.2.2 DISCUSSION

Males are able to deposit muscle at a faster rate than females relative to carcass weight (Section 3.1). Males have better forequarter muscle development than females, as is also suggested in Figs. 5 & 6.

Table 9: Estimation of total fibre number (N), number of myosin ATPase high fibres (NAH) and number of myosin ATPase low fibres (NAL) at two weights of muscle, from predictions of (a) WMA and MFA, (b) TAH and MAH, and (c) TAL and MAL, respectively, using the regressions given in Table 8.

Muscle	*RHOMBOIDEUS*					
Weight (g)	68 Male	68 Female	Sex Ratio†	410 Male	410 Female	Sex Ratio†
WMA (μm^2)	$2.96x10^8$a	$2.70x10^8$a	1.10	$1.23x10^9$b	$8.60x10^8$c	1.43
* Range	$2.69x10^8$	$2.39x10^8$		$1.13x10^9$	$7.34x10^8$	
	$3.27x10^8$	$3.05x10^8$		$1.34x10^9$	$1.00x10^9$	
MFA (μm^2)	$5.00x10^2$a	$8.36x10^2$b	0.60	$2.13x10^3$c	$3.01x10^3$d	0.71
* Range	$4.42x10^2$	$7.51x10^2$		$1.92x10^3$	$2.62x10^3$	
	$5.66x10^2$	$9.31x10^2$		$2.37x10^3$	$3.47x10^3$	
N	$5.93x10^5$a	$3.23x10^5$b	1.84	$5.77x10^5$a	$2.85x10^5$b	2.02
*Range	$5.06x10^5$	$2.75x10^5$		$5.05x10^5$	$2.31x10^5$	
	$6.94x10^5$	$3.80x10^5$		$6.60x10^5$	$3.52x10^5$	
TAH (μm^2)	$1.79x10^8$a	$1.59x10^8$a	1.13	$8.29x10^8$b	$5.94x10^8$c	1.40
*Range	$1.57x10^8$	$1.39x10^8$		$7.39x10^8$	$4.99x10^8$	
	$2.05x10^8$	$1.81x10^8$		$9.29x10^8$	$7.07x10^8$	
MAH (μm^2)	$4.61x10^2$a	$7.55x10^2$b	0.61	$2.23x10^3$c	$3.10x10^3$d	0.72
*Range	$3.99x10^2$	$6.62x10^2$		$1.97x10^3$	$2.61x10^3$	
	$5.32x10^2$	$8.61x10^2$		$2.52x10^3$	$3.68x10^3$	
NAH	$3.89x10^5$a	$2.10x10^5$b	1.85	$3.72x10^5$a	$1.92x10^5$b	1.94
*Range	$3.20x10^5$	$1.74x10^5$		$3.14x10^5$	$1.50x10^5$	
	$4.74x10^5$	$2.53x10^5$		$4.39x10^5$	$2.45x10^5$	
TAL (μm^2)	$1.15x10^8$a	$1.10x10^8$a	1.05	$3.87x10^8$b	$2.64x10^8$c	1.47
*Range	$9.92x10^7$	$9.33x10^7$		$3.41x10^8$	$2.13x10^8$	
	$1.34x10^8$	$1.29x10^8$		$4.39x10^8$	$3.27x10^8$	
MAL (μm^2)	$5.63x10^2$a	$9.84x10^2$b	0.57	$1.87x10^3$c	$2.81x10^3$d	0.67
*Range	$4.86x10^2$	$8.82x10^2$		$1.65x10^3$	$2.43x10^3$	
	$6.52x10^2$	$1.10x10^3$		$2.12x10^3$	$3.24x10^3$	
NAL	$2.05x10^5$a	$1.12x10^5$b	1.83	$2.07x10^5$a	$9.40x10^4$b	2.20
*Range	$1.66x10^5$	$9.17x10^4$		$1.73x10^5$	$7.27x10^4$	
	$2.52x10^5$	$1.36x10^5$		$2.47x10^5$	$1.22x10^5$	

Muscle	*SPLENIUS*					
Weight (g)	39 Male	39 Female	Sex Ratio†	292 Male	292 Female	Sex Ratio†
WMA (μm^2)	$3.26x10^8$a	$3.03x10^8$a	1.08	$1.64x10^9$b	$1.10x10^9$c	1.49
*Range	$2.93x10^8$	$2.77.10^8$		$1.50x10^9$	$9.45x10^8$	
	$3.62x10^8$	$3.31x10^8$		$1.79x10^9$	$1.27x10^9$	
MFA (μm^2)	$3.68x10^2$a	$6.82.10^2$b	0.54	$1.95x10^3$c	$2.65x10^3$c	0.74
*Range	$3.12x10^2$	$6.14x10^2$		$1.69x10^3$	$2.22x10^3$	
	$4.35x10^2$	$7.58x10^2$		$2.24x10^3$	$3.16x10^3$	
N	$8.85x10^5$a	$4.44x10^5$b	1.99	$8.42x10^5$a	$4.14x10^3$b	2.03
*Range	$7.27x10^5$	$3.87x10^5$		$7.12x10^5$	$3.28x10^5$	
	$1.08x10^6$	$5.09x10^5$		$9.95x10^5$	$5.21x10^5$	
TAH (μm^2)	$1.75x10^8$a	$1.48x10^8$a	1.18	$1.02x10^9$b	$6.77x10^8$c	1.50
*Range	$1.55x10^8$	$1.33x10^8$		$9.24x10^8$	$5.61x10^8$	
	$1.97x10^8$	$1.66x10^8$		$1.13x10^9$	$8.16x10^8$	
MAH (μm^2)	$3.15x10^2$a	$5.96x10^2$b	0.53	$1.93x10^3$c	$2.62x10^3$c	0.74
*Range	$2.65x10^2$	$5.25x10^2$		$1.66x10^3$	$2.12x10^3$	
	$3.74x10^2$	$6.75x10^2$		$2.24x10^3$	$3.23x10^3$	
NAH	$5.55x10^5$a	$2.49x10^5$b	2.23	$5.31x10^5$a	$2.58x10^5$b	2.06
*Range	$4.49x10^5$	$2.11x10^5$		$4.43x10^5$	$1.95x10^5$	
	$6.85x10^5$	$2.95x10^5$		$6.35x10^5$	$3.43x10^5$	
TAL (μm^2)	$1.52x10^8$a	$1.53x10^8$a	0.99	$5.90x10^8$b	$4.24x10^8$	1.39
*Range	$1.33x10^8$	$1.36x10^8$		$5.26x10^8$	$3.49x10^8$	
	$1.74x10^8$	$1.72x10^8$		$6.61x10^8$	$5.16x10^8$	
MAL (μm^2)	$4.61x10^2$a	$7.90x10^2$b	0.58	$1.90x10^3$c	$2.74x10^3$d	0.69
*Range	$3.93x10^2$	$7.18x10^2$		$1.66x10^3$	$2.34x10^3$	
	$5.42x10^2$	$8.68x10^2$		$2.18x10^3$	$3.21x10^3$	
NAL	$3.29x10^5$a	$1.93x10^5$b	1.70	$3.10x10^5$a	$1.55x10^5$b	2.00
*Range	$2.67x10^5$	$1.66x10^5$		$2.59x10^5$	$1.20x10^5$	
	$4.06x10^5$	$2.25x10^5$		$3.71x10^5$	$1.99x10^5$	

Table 9 continued

Muscle Weight (g)	18 Male	18 Female	Sex Ratio†	105 Male	105 Female	Sex Ratio†
	LONGISSIMUS CAPITIS					
WMA (μm^2)	3.05×10^{8}a	2.97×10^{8}a	1.03	1.31×10^{9}b	9.43×10^{8}c	1.39
*Range	2.67×10^{8}	2.61×10^{8}		1.17×10^{9}	7.82×10^{8}	
	3.49×10^{8}	3.38×10^{8}		1.47×10^{9}	1.14×10^{9}	
MFA (μm^2)	3.22×10^{2}a	5.15×10^{2}b	0.63	1.36×10^{3}c	1.90×10^{3}c	0.72
*Range	2.67×10^{2}	4.38×10^{2}		1.15×10^{3}	1.51×10^{3}	
	3.89×10^{2}	6.05×10^{2}		1.59×10^{3}	2.41×10^{3}	
N	9.47×10^{5}a	5.77×10^{5}b	1.64	9.69×10^{5}a	4.96×10^{5}b	1.95
*Range	7.52×10^{5}	4.69×10^{5}		7.94×10^{5}	3.67×10^{5}	
	1.19×10^{6}	7.09×10^{5}		1.18×10^{6}	6.69×10^{5}	
TAH (μm^2)	1.72×10^{8}a	1.58×10^{8}a	1.09	7.89×10^{8}b	4.09×10^{8}c	1.93
*Range	1.45×10^{8}	1.34×10^{8}		6.80×10^{8}	3.21×10^{8}	
	2.05×10^{8}	1.86×10^{8}		9.17×10^{8}	5.21×10^{8}	
MAH (μm^2)	2.79×10^{2}a	4.29×10^{2}b	0.65	1.23×10^{3}c	1.36×10^{3}c	0.90
*Range	2.23×10^{2}	3.59×10^{2}		1.01×10^{3}	1.05×10^{3}	
	3.51×10^{2}	5.13×10^{2}		1.49×10^{3}	1.76×10^{3}	
NAH	6.17×10^{5}	3.68×10^{5}b	1.67	6.42×10^{5}a	3.00×10^{5}b	2.14
*Range	4.63×10^{5}	2.89×10^{5}		5.02×10^{5}	2.11×10^{5}	
	8.21×10^{5}	4.69×10^{5}		8.21×10^{5}	4.28×10^{5}	
TAL (μm^2)	1.32×10^{8}a	1.37×10^{8}a	0.96	4.90×10^{8}b	5.34×10^{8}b	0.92
*Range	1.08×10^{8}	1.17×10^{8}		4.14×10^{8}	4.28×10^{8}	
	1.60×10^{8}	1.59×10^{8}		5.79×10^{8}	6.66×10^{8}	
MAL (μm^2)	3.97×10^{2}a	6.59×10^{2}b	0.60	1.53×10^{3}c	2.74×10^{3}d	0.56
*Range	3.35×10^{2}	5.57×10^{2}		1.32×10^{3}	2.15×10^{3}	
	4.71×10^{2}	7.79×10^{2}		1.77×10^{3}	3.49×10^{3}	
NAL	3.32×10^{5}a	2.07×10^{5}b	1.60	3.20×10^{5}ac	1.95×10^{5}bc	1.64
*Range	2.56×10^{5}	1.75×10^{5}		2.56×10^{5}	1.40×10^{5}	
	4.30×10^{5}	2.45×10^{5}		3.99×10^{5}	2.70×10^{5}	

Muscle Weight (g)	269 Male	269 Female	Sex Ratio	1703 Male	1703 Female	Sex Ratio
	LONGISSIMUS					
WMA (μm^2)	1.46×10^{9}a	1.35×10^{9}a	1.08	4.83×10^{9}b	4.59×10^{9}b	1.05
* Range	1.34×10^{9}	1.21×10^{9}		4.51×10^{9}	4.21×10^{9}	
	1.59×10^{9}	1.50×10^{9}		5.18×10^{9}	5.01×10^{9}	
MFA (μm^2)	7.19×10^{2}a	9.59×10^{2}b	0.75	2.57×10^{3}c	2.78×10^{3}c	0.92
*Range	6.23×10^{2}	8.48×10^{2}		2.28×10^{3}	2.52×10^{3}	
	8.31×10^{2}	1.01×10^{2}		2.90×10^{3}	3.07×10^{3}	
N	2.03×10^{6}a	1.41×10^{6}a	1.44	1.88×10^{6}a	1.65×10^{6}a	1.14
*Range	1.70×10^{6}	1.20×10^{6}		1.63×10^{6}	1.45×10^{6}	
	2.40×10^{6}	1.70×10^{6}		2.15×10^{6}	1.88×10^{6}	
TAH (μm^2)	1.22×10^{9}a	1.18×10^{9}a	0.84	4.00×10^{9}b	4.44×10^{9}b	0.90
*Range	1.11×10^{9}	1.06×10^{9}		3.69×10^{9}	4.05×10^{9}	
	1.34×10^{9}	1.32×10^{9}		4.34×10^{9}	4.86×10^{9}	
MAH (μm^2)	7.54×10^{2}a	1.03×10^{3}b	0.73	2.73×10^{3}c	2.95×10^{3}c	0.93
*Range	6.49×10^{2}	9.07×10^{2}		2.41×10^{3}	2.66×10^{3}	
	8.77×10^{2}	1.17×10^{3}		3.09×10^{3}	3.28×10^{3}	
NAH (μm^2)	1.62×10^{6}a	1.15×10^{6}a	1.41	1.46×10^{6}a	1.50×10^{6}a	0.97
*Range	1.36×10^{6}	9.69×10^{5}		1.26×10^{6}	1.31×10^{6}	
	1.93×10^{6}	1.36×10^{6}		1.70×10^{6}	1.73×10^{6}	
TAL (μm^2)	2.27×10^{8}a	1.63×10^{8}a	1.39	8.26×10^{8}b	6.04×10^{8}b	1.37
*Range	1.81×10^{8}	1.31×10^{8}		6.84×10^{8}	5.05×10^{8}	
	2.85×10^{8}	2.03×10^{8}		9.97×10^{8}	7.23×10^{8}	
MAL (μm^2)	5.65×10^{2}a	6.35×10^{2}a	0.89	1.95×10^{3}b	2.04×10^{3}b	0.96
*Range	4.71×10^{2}	5.54×10^{2}		1.69×10^{3}	1.82×10^{3}	
	6.77×10^{2}	7.29×10^{2}		2.26×10^{3}	2.29×10^{3}	
NAL (μm^2)	4.02×10^{5}a	2.57×10^{5}a	1.56	4.23×10^{5}a	2.96×10^{5}a	1.43
*Range	3.01×10^{5}	1.98×10^{5}		3.33×10^{5}	2.39×10^{5}	
	5.36×10^{5}	3.33×10^{5}		5.37×10^{5}	3.66×10^{5}	

Table 9 continued.

Muscle	*SEMITENDINOSUS*					
Weight (g)	109 Male	109 Female	Sex Ratio †	648 Male	648 Female	Sex Ratio †
WMA (μm^2)	$9.26x10^{8}$a	$8.69x10^{8}$a	1.07	$3.27x10^{9}$b	$2.96x10^{9}$b	1.10
*Range	$8.71x10^{8}$	$8.06x10^{8}$		$3.11x10^{9}$	$2.76x10^{9}$	
	$9.85x10^{8}$	$9.38x10^{8}$		$3.45x10^{9}$	$3.17x10^{9}$	
MFA (μm^2)	$9.06x10^{2}$a	$1.18x10^{3}$b	0.77	$3.53x10^{3}$c	$3.42x10^{3}$c	1.03
*Range	$8.53x10^{2}$	$1.02x10^{3}$		$3.36x10^{3}$	$2.99x10^{3}$	
	$9.62x10^{2}$	$1.37x10^{3}$		$3.71x10^{3}$	$3.90x10^{3}$	
N	$1.02x10^{6}$a	$7.36x10^{5}$b	1.39	$9.27x10^{5}$ab	$8.66x10^{5}$ab	1.07
*Range	$9.38x10^{5}$	$6.24x10^{5}$		$8.63x10^{5}$	$7.47x10^{5}$	
	$1.11x10^{6}$	$8.68x10^{5}$		$9.97x10^{5}$	$1.00x10^{5}$	
TAH (μm^2)	$7.76x10^{8}$a	$6.98x10^{8}$a	1.11	$2.89x10^{9}$b	$2.59x10^{9}$b	1.12
*Range	$7.23x10^{8}$	$6.43x10^{8}$		$2.72x10^{9}$	$2.41x10^{9}$	
	$8.32x10^{8}$	$7.57x10^{8}$		$3.06x10^{9}$	$2.79x10^{9}$	
MAH (μm^2)	$9.24x10^{2}$a	$1.22x10^{3}$a	0.75	$3.65x10^{3}$b	$3.56x10^{3}$b	1.03
*Range	$7.61x10^{2}$	$1.05x10^{3}$		$3.10x10^{3}$	$3.11x10^{3}$	
	$1.12x10^{3}$	$1.41x10^{3}$		$4.30x10^{3}$	$4.07x10^{3}$	
NAH	$8.39x10^{5}$a	$5.74x10^{5}$a	1.46	$7.91x10^{5}$a	$7.28x10^{5}$a	1.09
*Range	$6.82x10^{5}$	$4.84x10^{5}$		$6.65x10^{5}$	$6.24x10^{5}$	
	$1.03x10^{6}$	$6.80x10^{5}$		$9.41x10^{5}$	$8.48x10^{5}$	
TAL (μm^2)	$1.24x10^{8}$a	$1.47x10^{8}$a	0.84	$3.26x10^{8}$b	$3.21x10^{8}$b	1.02
*Range	$8.60x10^{7}$	$9.57x10^{7}$		$2.41x10^{8}$	$2.18x10^{8}$	
	$1.77x10^{8}$	$2.25x10^{8}$		$4.42x10^{8}$	$4.72x10^{8}$	
MAL (μm^2)	$7.81x10^{2}$a	$1.03x10^{3}$a	0.76	$2.76x10^{3}$b	$2.59x10^{3}$b	1.07
*Range	$6.41x10^{2}$	$8.86x10^{2}$		$2.34x10^{3}$	$2.26x10^{3}$	
	$9.51x10^{2}$	$1.20x10^{3}$		$3.26x10^{3}$	$2.97x10^{3}$	
NAL	$1.58x10^{5}$a	$1.43x10^{5}$a	1.10	$1.18x10^{5}$d	$1.24x10^{5}$a	0.95
*Range	$1.05x10^{5}$	$9.05x10^{4}$		$8.36x10^{4}$	$8.23x10^{4}$	
	$2.39x10^{5}$	$2.25x10^{5}$		$1.67x10^{5}$	$1.86x10^{5}$	

* 95% confidence limits; probability of a value outside these limits < 0.05. Values of area and number within each row, not followed by the same letter are outside each others confidence limits.

† Value in male/Value in female.

Fig. 6, based on the *b* values of individual muscles, provides a more accurate representation of muscle distribution in both sexes than Fig. 5, which shows muscle groups. The grouping of individual muscles according to anatomical location (Butterfield, 1964b, Butterfield and Berg, 1966b) and the consideration of each group as a functional unit, obscures the fact that the growth patterns of individual muscles, as classified by their *b* values, within each anatomical/functional group are often different from one another. This is apparent from the results of the present findings and that of Butterfield and Berg (1966a & b) and Bergström (1978) for cattle, Lohse, Moss and Butterfield (1971) for sheep, and Davies (1974b) for pigs.

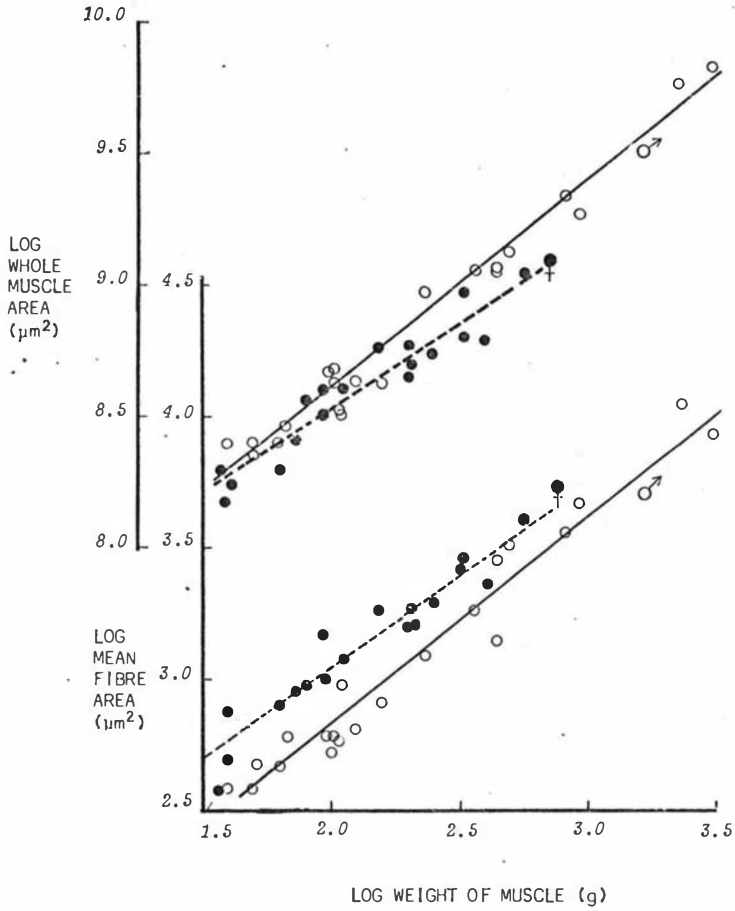


Figure 13: Allometric change in transverse sectional whole muscle area and mean fibre area relative to the weight of *m. rhomboideus* in male (○) and female (●) Jersey cattle, from birth to maturity.

Where differences in muscle distribution are small, such as between breeds (Butterfield, 1964b; Mukhoty and Berg, 1973; Truscott, Lang and Tulloh, 1976; Kempster, Cuthbertson and Smith, 1976; Berg, Anderson and Liboriussen, 1978b; Bergström, 1978) and between male and female cattle (Berg and Mukhoty, 1970; Mukhoty and Berg, 1973; Bergström, 1978; Jones, Price and Berg, 1980) the growth ratio of individual muscles is likely to be more informative than that of muscle groups. The manner in which groups of muscles are assembled for comparison is thus likely to affect the conclusions of an experiment. It could also affect the validity of comparison between experiments, especially when these have been designed for different purposes, such as breed, sex or nutritional comparison.

3.2.2.1 Sex differences in the growth of muscle groups and individual muscles

Males have better developed neck muscles than females as suggested by the growth ratios, when expressed either as a muscle group (Table 3) or as individual muscles (Table 4). Although significant sex differences in growth ratios are observed for the sublumbar and thoracic muscle groups (Table 3), it should be noted that the sublumbar group comprised only three muscles and that the intrinsic muscles of the thorax when considered individually (Table 4) showed no significant sex difference.

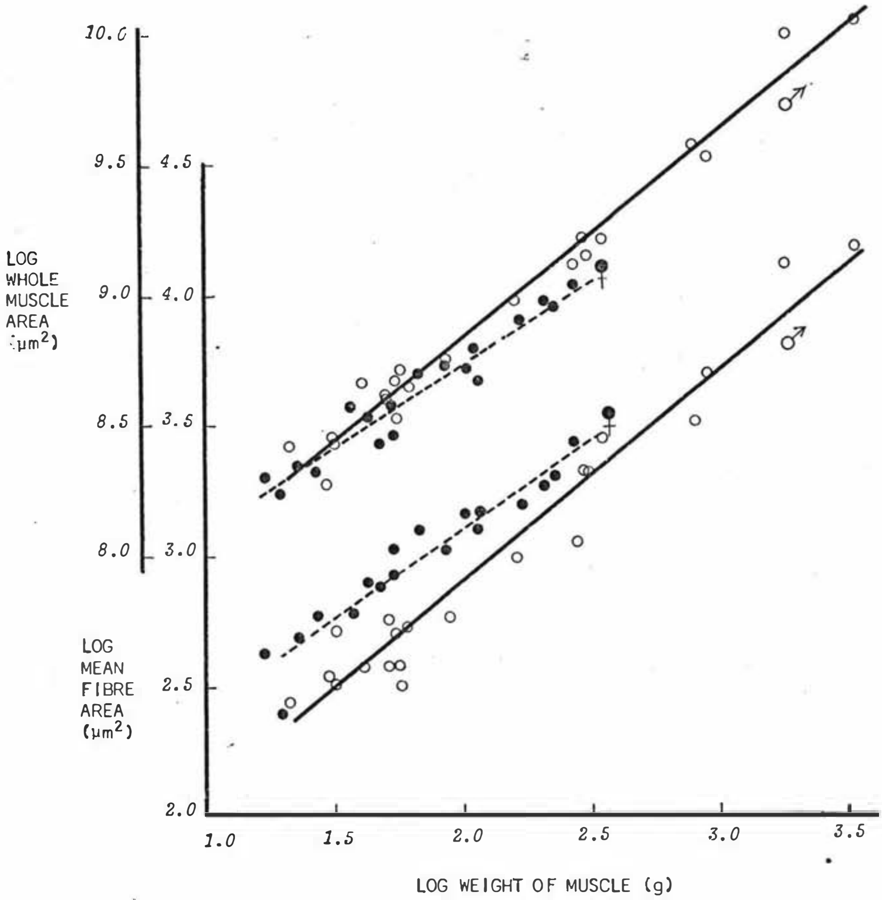


Figure 14: Allometric change in transverse sectional whole muscle area and mean fibre area relative to the weight of *m. splenius* in male (○) and female (●) Jersey cattle, from birth to maturity.

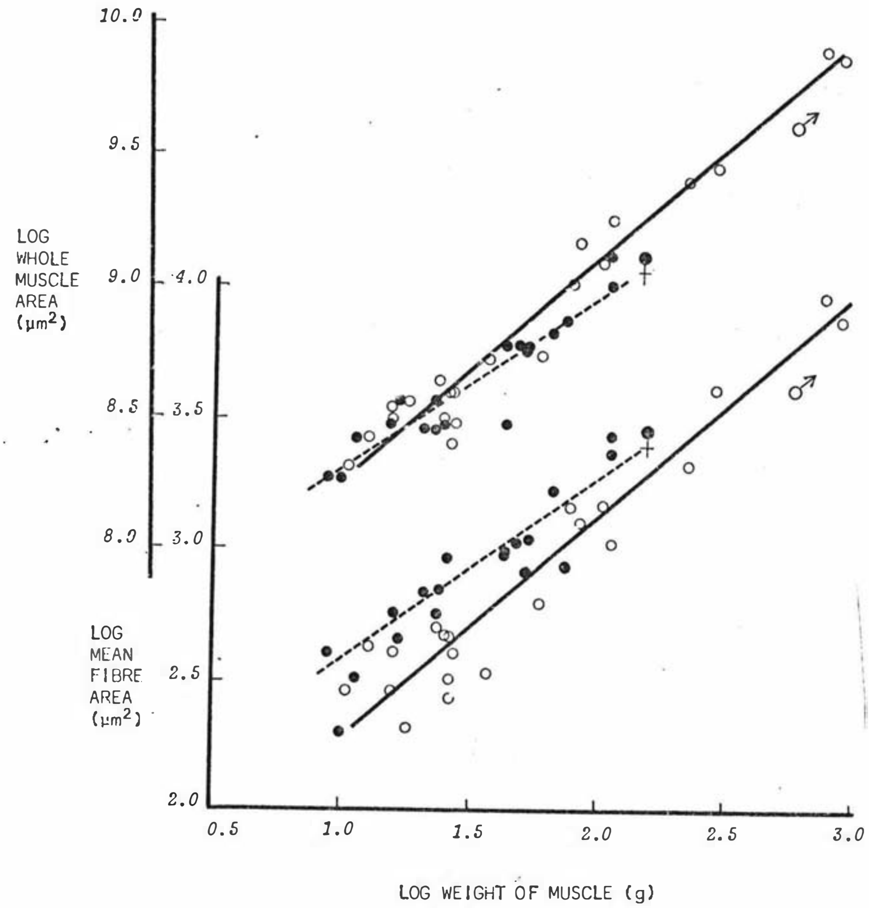


Figure 15: Allometric change in transverse sectional whole muscle area and mean fibre area relative to the weight of *m. longissimus capitis* in male (○) and female (●) Jersey cattle, from birth to maturity.

Berg and Butterfield (1976) discussed the effect of sex on the growth patterns of muscle groups, based on the work of Berg (1968, cited by Berg and Butterfield, 1976, p.101) and Berg and Mukhoty (1970). Two sets of allometric growth ratios for nine standard muscle groups for Shorthorn-cross cattle were given. The set which omitted the four calves is shown in Table 10. This is because the use of these calves as a common group to represent bulls and heifers may not be valid because it ignores the influence of sex on muscle weight at that stage of growth. Evidence that changes related to sex occur very early postnatally will be given in the following section (3.2.2.2).

Table 10 also includes the results of Bergström (1978). These earlier studies confirm that any significant differences in muscle growth between males and females are most likely to occur in muscles of the forequarter and in the neck in particular.

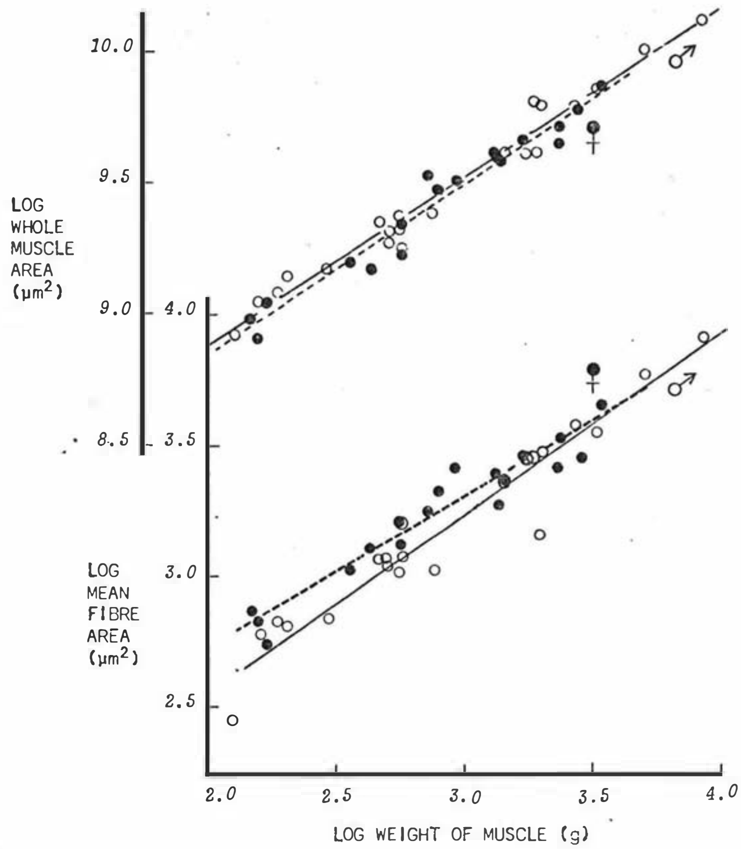


Figure 16: Allometric change in transverse sectional whole muscle area and mean fibre area relative to the weight of *m. longissimus* in male (○) and female (●) Jersey cattle, from birth to maturity.

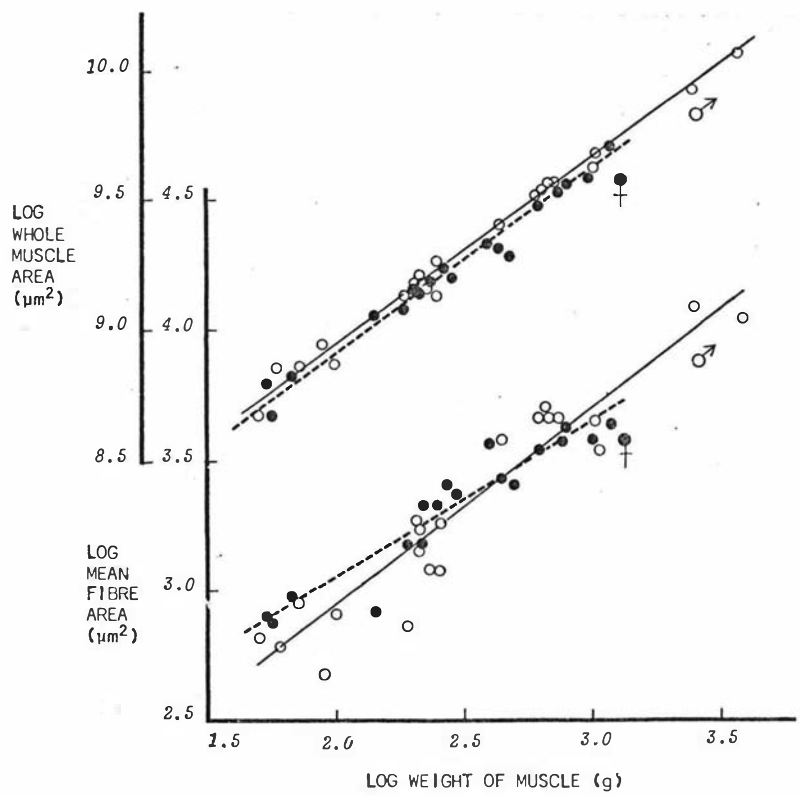
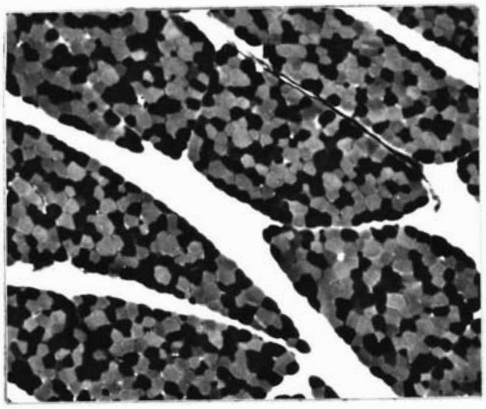


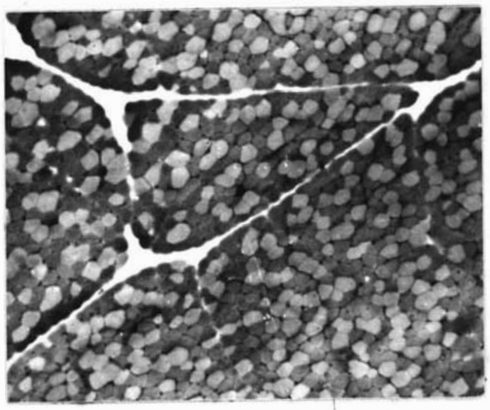
Figure 17: Allometric change in transverse sectional whole muscle area and mean fibre area relative to the weight of *m. semitendinosus* in male (○) and female (●) Jersey cattle, from birth to maturity.

MALE FEMALE

(a) *M. rhomboideus*

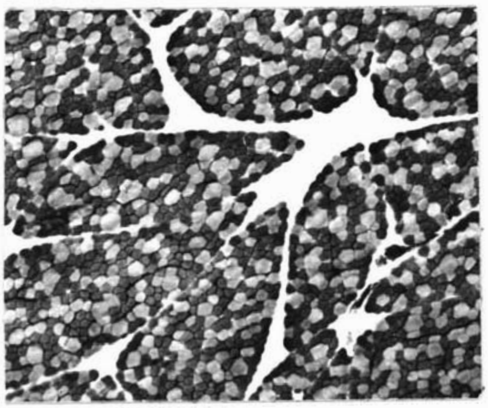


25 kg liveweight

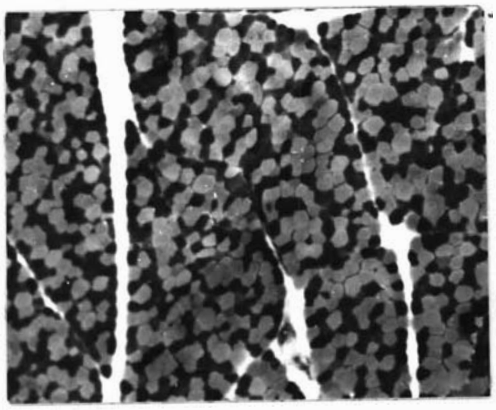


20 kg liveweight

(b) *M. splenius*

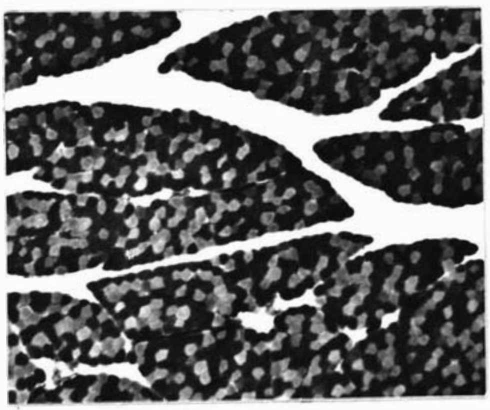


20 kg liveweight

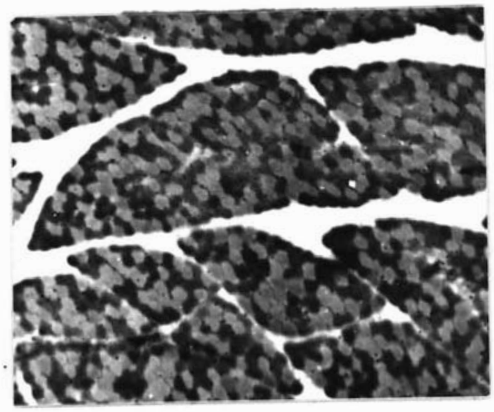


20 kg liveweight

(c) *M. longissimus capitis*



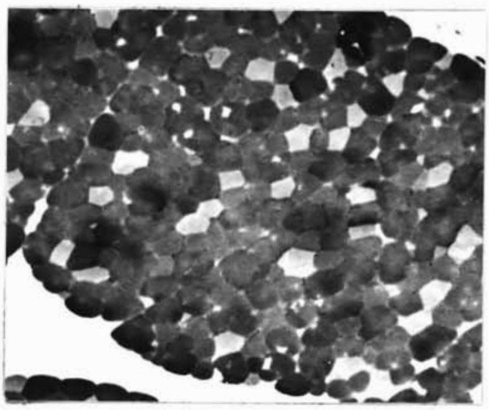
20 kg liveweight



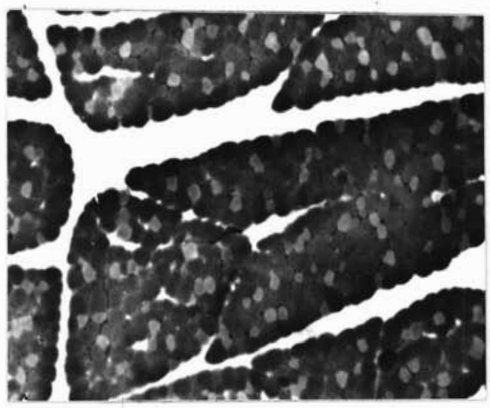
20 kg liveweight

MALE | FEMALE

(d) *M. longissimus*

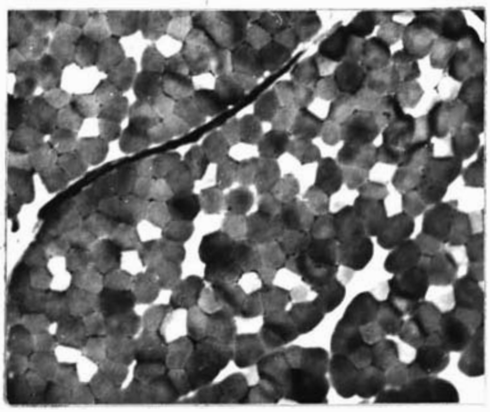


75 kg liveweight

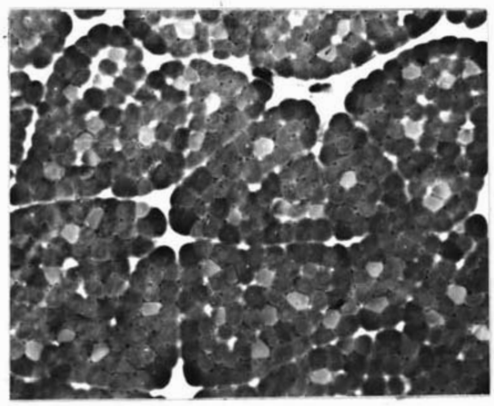


20 kg liveweight

(e) *M. semitendinosus*



50 kg liveweight

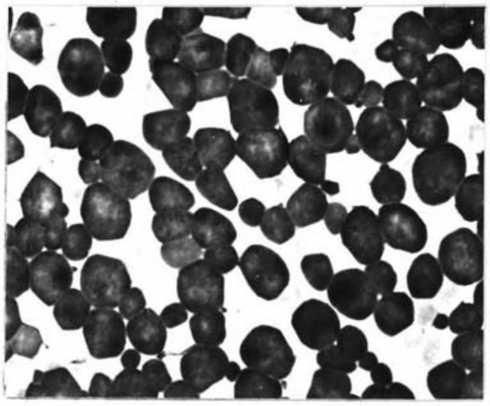


20 kg liveweight

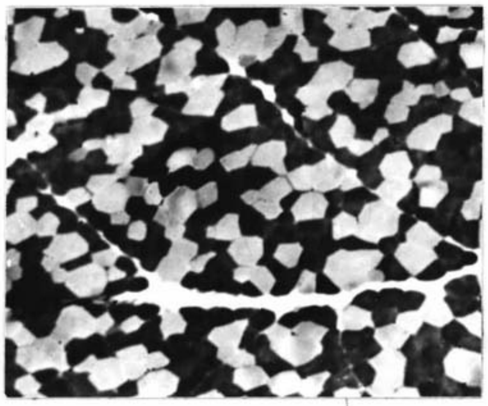
Figure 18: Photomicrographs of transverse sections of *mm. rhomboideus*, *splenius*, *longissimus capitis*, *longissimus* and *semitendinosus*, stained for myosin ATPase (magnification X 190). The muscles are from male and female Jersey cattle at stages of growth when histochemical sex differences in the neck muscles (a) to (c) are not obvious.

MALE | FEMALE

(a) *M. rhomboideus*

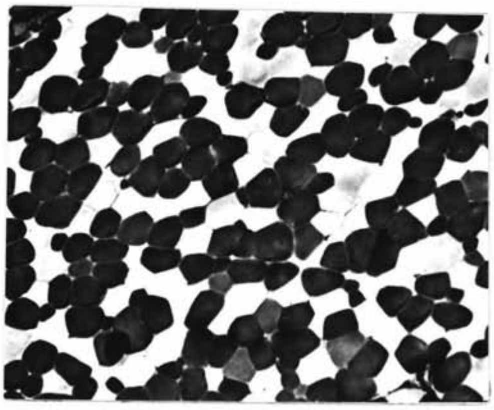


220 kg liveweight

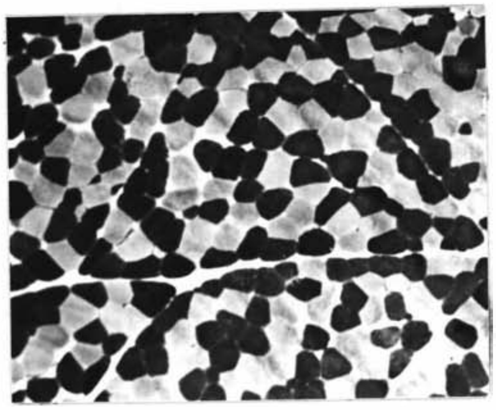


220 kg liveweight

(b) *M. splenius*

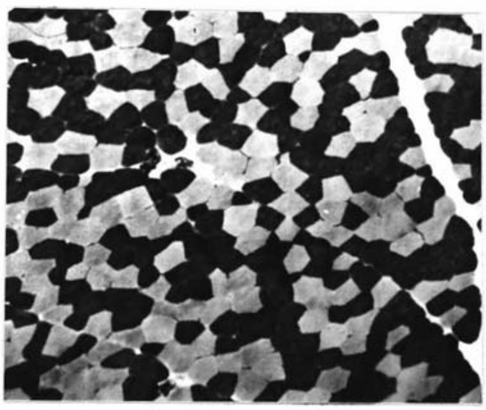


220 kg liveweight

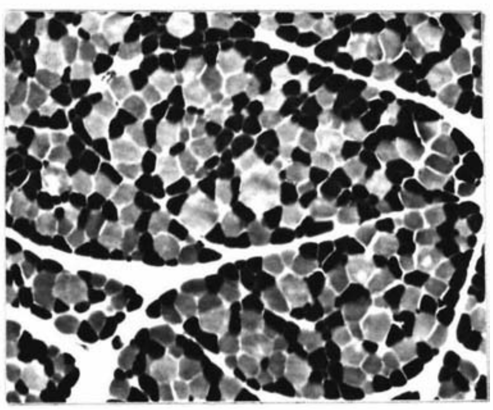


220 kg liveweight

(c) *M. longissimus capitis*



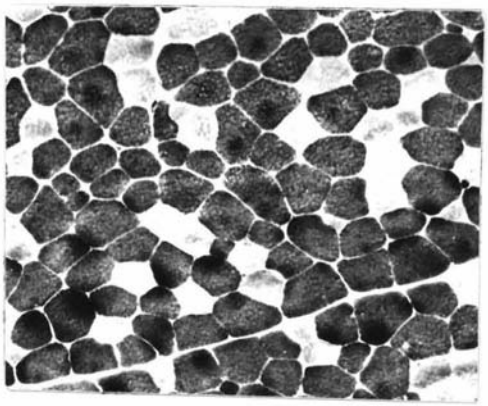
180 kg liveweight



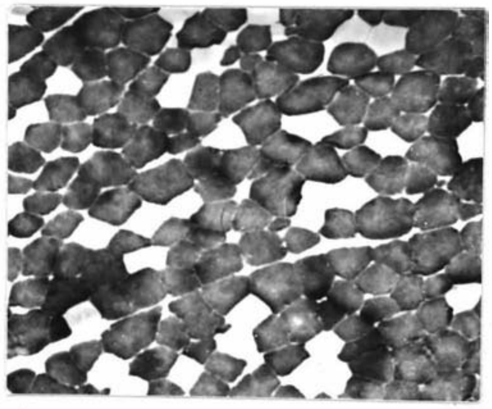
310 kg liveweight

MALE FEMALE

(d) *M. longissimus*

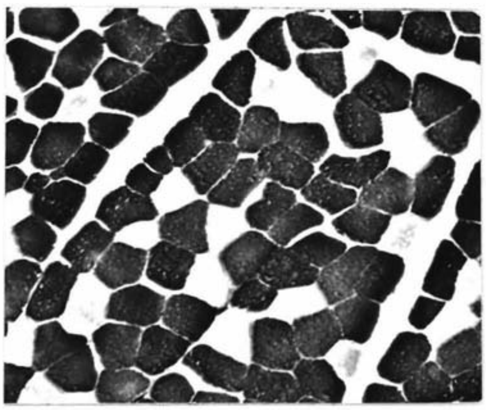


310 kg liveweight

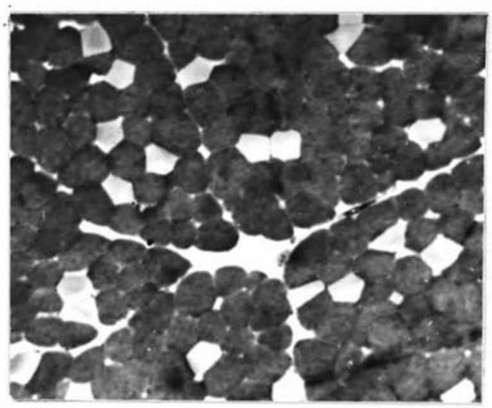


310 kg liveweight

(e) *M. semitendinosus*



180 kg liveweight



180 kg liveweight

Figure 19: Photomicrographs of transverse sections of *mm. rhomboideus, splenius, longissimus capitis, longissimus* and *semitendinosus,* stained for myosin ATPase (magnification X 190). The muscles are from male and female Jersey cattle at stages of growth when histochemical sex differences in the neck muscles (a) to (c) become apparent.

Table 10: Allometric growth ratios (*b*), and their standard errors for standard muscle groups of male and female (a) Shorhorn-cross (Berg, 1968, cited by Berg and Butterfield, 1976) and (b) Dutch Friesian cattle (Bergström, 1978).

(a) Shorthorn-cross cattle

Standard muscle group	Male	Female	Sex Diff.
Proximal pelvic limb	0.84±.03	0.93±.06	NS
Distal pelvic limb	0.92±.03	1.05±.06	NS
Spinal column	0.97±.02	1.10±.06	NS
Abdominal	1.12±.05	1.28±.08	NS
Proximal thoracic limb	1.00±.02	0.92±.04	NS
Distal thoracic limb	1.00±.04	0.83±.06	P <.05
Thoracic limb to thorax	1.49±.03	1.06+.04	P <.001
Thoracic limb to neck	1.28±.05	1.18±.07	NS
Neck and thorax	1.21±.06	0.97±.05	P <.05

(b) Dutch Friesian cattle

Standard muscle group	Male	Female	Sex Diff.
Proximal pelvic limb	0.98±.008	0.99±.008	NS
Distal pelvic limb	0.83±.009	0.82±.009	NS
Back mid loin	1.03±.005	1.05±.009	NS
Sublumbar	1.01±.008	1.03±.011	NS
Thorax and abdomen	1.11±.008	1.11±.01	NS
Proximal thoracic limb	0.97±.005	0.95±.008	NS
Distal thoracic limb	0.82±.010	0.82±.016	NS
Neck	1.03±.016	0.98±.014	P <.05
Shoulder girdle	1.04±.006	1.04±.010	NS

Jones *et al.* (1980) showed no differences in *b* ratio in their joint groups, between male and female Hereford and 'Dairy Synthetic' cattle breeds. However, jointing may not be sufficiently sensitive to demonstrate sex differences because the neck group was included with the 'chuck' group, which also comprised the extrinsic muscles of the shoulder and brachial and cranial thoracic muscles. In the present study, the brachial and thoracic muscle groups did not grow as fast as the neck and extrinsic shoulder muscles (Table 3 and 10). It is also relevant to note that there are differences in the grouping of muscles between the present study and those referred to in Table 10.

Bulls are said to have a higher proportion of muscles in the neck and shoulder regions, but a lower proportion of muscles in the proximal hind limb region than heifers (Berg and Mukhoty, 1970; Mukhoty and Berg, 1973). However in any analysis where percentages are used or values are expressed in relation to a total, an increase in proportion in one region must mean a decrease in some other regions. It is therefore difficult to distinguish between real and apparent effects. As observed by Berg and Mukhoty (1970), visual judgement would suggest a higher proportion of proximal hind limb muscles in bulls than heifers, although their results using percentages showed otherwise. In this study, because y was part of x, then any increase in relative growth of some muscles would mean an apparent decrease in relative growth of some other muscles. This is illustrated in the topographical distribution of muscle groups in the male where only the brachial muscle group grew similar to TSM (Fig. 5). Similarly, Fig.6 showed that while more than half the total number of the muscles studied (60 muscles) grew at similar rate to TSM, in females, less than half the total number (46 muscles) was similar in their growth rate to TSM, in males. Hence, the greater growth of some of the extrinsic muscles of the shoulder and intrinsic muscles of the neck in males could have contributed to the apparent low growth ratios of some muscles, such as those found in the pelvic and thoracic regions. The converse argument that the low growth of the muscles in the pelvic region causes the apparent high growth of some forequarter muscles could not be substantiated because the b values of the pelvic (proximal pelvic limb) muscle group were not significantly different between male and female cattle in the present (Table 3) and the other two studies (Table 10), each of which used a different breed. Therefore, the neck development in males is real.

The results on Dutch Friesian cattle (Bergström, 1978) showed only the neck muscle group growing significantly differently between males and females. When the muscles which grew significantly slower in male than female Jersey cattle (Table 5) were compared between sexes in the Friesian, it was observed that none of these muscles was significantly different in their b values between sexes in the Friesian. However, the muscles which grew significantly faster in male than female Jersey cattle, namely *mm. splenius, longissimus capitis et atlantis* and *triceps brachii,* showed significant differences in their b values in the Friesian. It is possible that the Dutch Friesian breed is less sexually dimorphic in muscle development than the Jersey breed.

At 55.0 kg TSM, male Jersey cattle produced 1.2 kg more muscle than females, from the muscles showing a sex difference in growth ratios (Table 5). Males are more efficient in producing muscle than females because they develop 55.0 kg TSM at a lighter weight (82.6 kg HCWT) than do females (96.5 kg HCWT). Furthermore, when the total weight of the muscles which grew significantly slower in males than females is expressed as a percentage of HCWT, the difference between sexes is only 0.1% HCWT, compared with a difference of 2.5% TSM weight. In the case of the muscles which grew significantly faster in males than females, the difference between sexes was 4.1% HCWT which is about similar to the value of 4.5% TSM weight. Additionally, males have a higher potential than females to produce muscle because at 55.0 kg TSM, male Jersey cattle are approximately at half maturity (see Table 2), while females are at about full maturity.

Table 5 shows that at 55.0 kg TSM, males have bigger *mm. splenius, longissimus capitis* and *rhomboideus* than females, in order of 2.9, 2.1 and 1.8 times, respectively. At maturity, there will be an even bigger weight difference between sexes. Hence these muscles are good examples to illustrate the differences in the potential of certain muscles to grow between males and females, and for an investigation into the mechanism by which differences in muscle growth can be achieved between sexes. This mechanism may also explain the manner in which other genotypic variants, namely individuals, breeds and species, may differ in muscle distribution.

3.2.2.2 Biological significance in the breaks in allometry of the testis and *mm. rhomboideus, splenius* and *longissimus capitis*.

Breaks in allometric plots are not accidental but are connected with definable changes in underlying processes, such as sexual maturation (Bertalanffy, 1960). The break in allometry of the testis shown here for Jersey cattle (Fig. 7) has also been reported for the mouse, rat, elephant and human (Brody, 1945; Bertalanffy, 1960; Spencer, 1968). The breaks for each species were considered to occur at a 'pubertal' weight. In this study, the break in allometric growth of the three neck muscles relative to TSM in males (Figs. 8, 9 and 10) occurred at about the same point as the break in allometry of the testis, approximating to when the calves were 50 kg live weight (Fig. 20).

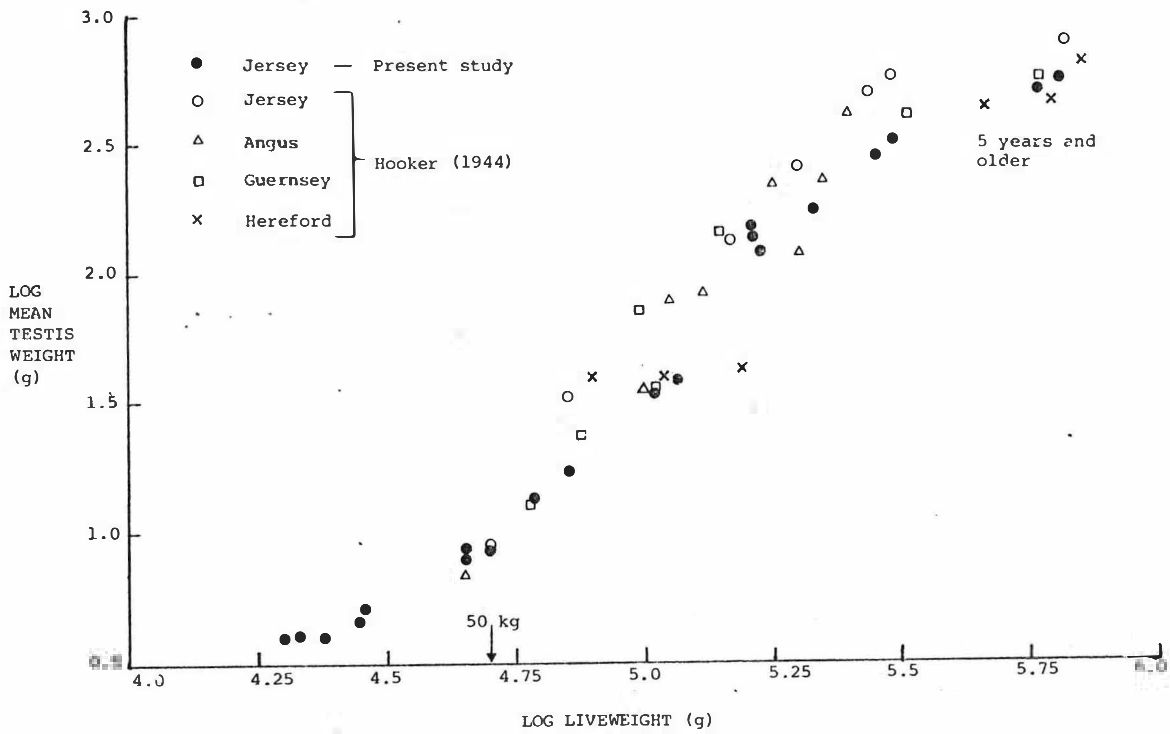


Figure 20: Allometric growth of testis relative to liveweight in four breeds of cattle.

The testis has basically two functions, namely, spermatogenesis and steroidogenesis (Faulkner, 1971). Puberty is defined in cattle on a spermatogenetic basis by the appearance of mature spermatozoa in the epididymis or ejaculate (Hooker, 1944; McDonald, 1971). In a study involving Jersey, Ayshire, Guernsey and Holstein bulls, Hooker (1944) indicated that puberty occurred at around 9 months. This approximates to a bull of about 150 kg bodyweight. However, this definition of puberty does not consider the growth promoting effects of androgens. Hooker (1944) concluded that because the rapid growth of the testis was accompanied by only a small increase in androgen levels, the increased growth might be due to an increased responsiveness of the testicular tissues to androgens. Similarly, the significant increase in allometry in phase 2 from that in phase 1 for testis (Table 6) and the neck muscles (Table 7) can be explained by an increase responsiveness of the tissues of these structures to steroids, arising from the interstitial cells in the testis or other sources such as the adrenal cortex. Hence, a break in allometry signifies the beginning of somatic 'prepubertal' changes and when secondary sex characteristics, such as an increase in muscle development in the neck, begin to manifest. In Jersey cattle, the process of becoming sexually dimorphic begins at a light liveweight of about 50 kg (Fig 20) corresponding to an age of about 35 days (Appendix 4), which is 'prepubertal'.

In Fig. 20, the data of Hooker (1944) on the weight of testis and bodyweights of the four cattle breeds was plotted on double logarithmic coordinates, together with the data of the present study. Although Hooker's data did not include calves from birth, it showed that regardless of breed the growth of testis was related to body weight More significantly, it confirmed that in bulls of five years and older, the relative growth of the testis declines. The testis of the bull appear to reach a determinate size at about 5 years. An equivalent decline in relative growth was however, not evident for the neck muscles (Figs. 8 to 10).

Breaks in relative growth of muscles have been reported for cattle (Butterfield and Berg, 1966a; Bergström, 1978) and sheep (Lohse *et al.*, 1971; Lohse, 1973; Jury, Fourie and Kirton, 1977). These breaks were arbitrarily set at various points during growth. Their biological significance was not, however, discussed.

3.2.2.3 Sources of variation in muscle growth studies

In this study, samples were removed before rigor mortis and were assumed to have contracted fully after removal. The procedures of muscle sampling and the general processing of the muscles for enzyme histochemistry was similar for all muscles and between sexes. Sampling sites for each of these muscles were defined anatomically in order to reduce errors arising from site variation within a muscle, as has been discussed by Johnson and Beattie (1973). The results obtained are specific to this study and are used in a comparative way to demonstrate differences or similarities between male and female cattle within a single breed. The wide postnatal growth range and the use of logarithmic regressions reduces the contribution of errors arising from individual variation, sampling and processing, to the overall pattern of growth.

3.2.2.4 Change in area measurements relative to the weight of individual muscles.

During the growth of a muscle there is a change in size and perhaps, in shape, both of which can be characterized, in part, by measuring the change in areas (WMA, MFA, TAH, MAH, TAL and MAL) and the weight of muscle. This study considered these changes and differed from other studies on muscle growth (Table 11) in many ways. The growth changes of each muscle in area dimensions, which represented y components, were related to the weight of the muscle (x), using double logarithmic regressions. In relating changes to the weight of the muscle studied, it was possible to make comparisons between sexes of the y values as well as estimated values of fibre number (N, NAH and NAL) at the same muscle weight. This method of comparison was adopted because the weight of a muscle is a more precise indicator of the stage of growth of the particular muscle than the age or bodyweight of the animal. No other studies have compared muscle dimensions between groups on the basis of individual muscle weight. This basis of comparison is also useful for studies of nutritional effects on muscle fibre growth, because apparent differences in fibre size due to nutrition (*cattle:* Robertson and Baker 1933; Yeates, 1964 *sheep*: Joubert, 1956; *pigs*: Staun, 1963) may be due to differences in muscle weight.

Because growth is a multiplicative process, the variance of x is multiplicative and not additive. Logarithms therefore stabilize the variance (Snedecor and Cochran, 1967) such that the covariance of x and y becomes independent of x. The increasing covariance in measurements, such as MFA or WMA, during growth of *mm. longissimus* and *semitendinosus* is not accounted for statistically by Bendall and Voyle (1967). Therefore, their conclusions of a decrease in fibre number, which is not demonstrated here in either sex, should be re-examined. In addition, their use of MFA as the x variable statistically implies that no errors will arise from the measurement of area. Less error is involved in weighing a muscle than in measuring the area. Therefore muscle weight is a better covariate to use than MFA.

Table 11: References of cattle and sheep studies on muscle size, where at least two sexes were used, to show the muscles studied, the different ages or weights at which samples were taken and the absence of information on total fibre number and rate of change in fibre size. Information on the present study is also included in this table for comparison.

(a) CATTLE

References*	Breed, number of animals & sex †	Range	Muscle	Measurements	Basis of comparison
Brady (1937).	Hereford & Shorthorn (6C); Holstein (7F).	Unknown	Triceps brachii; Longissimus dorsi; Adductor; Semitendinosus.	Samples pooled from the different muscles to give mean diameter of muscle fibres and number of fibres per bundle.	Unknown (carcass grade?)
Holmes & Ashmore* (1972)	Culards (3M, 3F); Heterozygous (8M, 8F); Normals (5M, 8F).	4 to 66 weeks	Triceps longus; Cutaneus trunci; Semitendinosus.	Mean area of 'red' & 'white' fibres and all fibres. % fibres & % area of 'white'. Ratio of area of 'white' fibres to area of 'red' fibres.	Biopsies at 4, 16, 26 & 66 weeks of age
Cornforth *et al.* (1980)	Angus (6F, 4C); Hereford (5F, 2C); Holstein (6F, 6C).	40 to 318 kg liveweight	Biceps femoris	Mean transverse sectional area of 'red' fibre.	Biopsies at liveweights of 40, 50, 85, 181, 318 kg & a final salughter weight which differ between sexes
Spindler, Mathias & Cramer (1980)	Angus (2F, 4C); Hereford (2F, 8C); Holstein (4F, 4C).	28 to 392 days	Biceps femoris	Mean transverse sectional area of 'red', white & intermediate	Biopsies at 28 112, 168, 224, 280, 336 & 392 days
Tan* (Present study)	Jersey (21M, 18F)	Birth to maturity	Rhomboideus; Splenius; Longissimus capitis; Longissimus; Semitendinosus.	Whole muscle area; mean fibre area; total area of ATPase high fibres: mean AH fibre area; total area of ATPase low fibres; mean AL fibre area. Estimated number of total fibres, & total AH & AL fibres. Muscle weight.	Log transformed data; regression equations; at the same muscle weight.

(b) SHEEP

References*	Breed, number of animals & sex †	Range	Muscle	Measurements	Basis of comparison
Joubert* (1956)	Suffolk x Border Leicester - Cheviot (20M, 20F)	Birth to 290 days	Longissimus dorsi; Rectus femoris; Gastrocnemius.	Samples pooled from the different muscles to give a mean diameter of muscle fibres.	Birth, 13.6 kg carcass weight & 290 days
Moody, Tichenor, Kemp & Fox (1970)	Crossbreed (6M, 6C)	36 to 54 kg slaughter weight	Longissimus; Semitendinosus.	Mean fibre diameter	36, 45 & 54 kg slaughter weight
Moody *et al.* (1980)	Different crossbreeds Experiment 1: (16F, 16C) Experiment 2: (18M, 18C)	41 to 50 kg slaughter weight	Longissimus	Mean fibre diameter of 'βR' 'αR' & 'αW' Fibre type number as % of total number of fibres per 10 cm^2 area.	Unknown (pooled from different slaughter weights?)

* References where males and females of one breed were used.

† Male = M; Female = F; Castrate = C.

The presentation of the growth changes in WMA and MFA relative to muscle weight as a double logarithmic regression allowed growth to be viewed as a continuous process and not in a staccato manner, as observed in constant endpoint analysis. More importantly, the rate of change in y components is defined here by their b values which can be statistically tested for significance between sexes and between components within each sex.

In a study of muscle or muscle fibre shape where the dimension, area, is related to another dimension, weight, double logarithmic regressions permit a statistical analysis determining whether dimensionally the muscle or fibre has maintained its shape. For proportionality, a structure must increase its area by the 2/3 power of its weight (Brody, 1945). Therefore, logarithmically, if the regression coefficient (b) is significantly different from 0.667, then a change in shape may have occurred. Hence, in the present study b values of WMA and MFA, which are significantly greater than 0.667 means a change in shape of the muscle and muscle fibre, respectively, suggesting that muscle and fibre 'hypertrophy' has occurred. Furthermore, if these values are also significantly different between sexes, they suggest that the muscles such as *mm. rhomboideus, splenius* and *longissimus capitis* (Table 8) are sexually dimorphic. An increase in size is not necessarily hypertrophy; dimensionally, it may merely represent a more advanced stage of normal growth.

Mm. rhomboideus, splenius and *longissimus capitis* differ between male and female Jersey cattle in their allometric growth pattern. No previous studies have been made on the cellular growth of these muscles. In male and female Jersey cattle, WMA, MFA, TAH, MAH, TAL and MAL increased with increasing weight for each muscle. The references in Table 11, where growth changes in muscle dimensions were studied, as well as other studies (Staun, 1963; Hegarty, 1971; Goldspink, 1972; Malina, 1978) agree that these dimensions will increase during positive growth. However, authors differ in their conclusions as to whether there is a sex difference in muscle or muscle fibre size, probably because of the different basis of comparison, muscles studied, growth range investigated, breed or species. The present results show that, depending on the stage of growth, muscle fibre size may be smaller, equal or bigger in males than females (Table 9). It is less important to know whether there is a difference in size at a certain point of growth, than it is to know the mechanisms by which this difference is achieved.

The most significant findings, explaining differences between sexes in muscle growth, were the differences in total number of muscle fibres in the neck muscles (Table 9) and the different rate of increase in muscle and fibre size (Table 8). Kochakian (1966) showed that the sexual dimorphism of growth of the muscles of mastication of the guinea pig is androgen dependent. Presumably the effect of androgen is to increase fibre size.

A difference between sexes in total fibre number as well as in the number of fibres of each type has not been reported previously. The importance of fibre number accounting for sex difference can be implied from the sex ratios for MFA at the heavier weight (Table 9) showing values between 0.71 and 0.74 for the neck muscles, as compared to the ratios of 0.92 and 1.03 for *mm. longissimus* and *semitendinosus*, respectively. Yet the sex ratios for WMA showed values of 1.39 to 1.49 for the neck muscles and 1.05 and 1.10 for the other two muscles.

The results on the number of each fibre type also show that males have significantly more AH and AL fibres in the neck muscles than females. However, the AH fibres in the neck muscles contributed more to the increase in size of the muscles than AL fibres in males, and also to the difference between sexes, in terms of area and rate of increase. In the study by Holmes and Ashmore (1972) (Table 11), males had bigger mean areas of 'white fibres', which would be AH fibres, than females at 66 weeks of age. However, because they did not compare at the same muscle weight, the difference of 18% reported could be explained by a difference in the stage of muscle development.

Findings based on myosin ATPase histochemistry provide some indication of function (Cassens, Cooper and Morita, 1969; Davies and Gunn, 1972; Davies, 1972) and in this study provided evidence as to the degree of functional difference in the neck muscles of males and females (Table 9).

Thus the neck muscles of males appear better adapted than females for very rapid movement, such as in aggressive behaviour, because AH fibres generally have a high intrinsic speed of shortening and compared to AL fibres is less suited for a postural function (Gauthier, 1971; Peter, 1971; Close, 1972; Holloszy and Booth, 1976). This difference in fibre type morphology is androgen dependent; direct evidence of the influence of hormones on fibre type, and on myosin ATPase activity in particular, was observed in *m. soleus* of the mouse (Vaughan *et al.* 1974) and in *m. flexor carpi radialis* of the frog (Melichna *et al.* 1972). In *m. soleus* of the mouse, males had a significantly higher percentage of AH fibres than females and castrates, the last two sexes having similar percentage of AH fibres. However, whether *m. soleus* is functionally different between sexes in any species is doubtful. *M. flexor carpi radialis* in the frog is associated with the 'clasping reflex' of the male during mating. Melichna *et al.* (1972) observed that seasonally in the male frog, fibres with low ATPase activity were present while in females, all fibres had a relatively high ATPase activity. Additionally, the muscle in the male frog showed slower contraction time than females. These findings support the tonic function of the muscle during clasping by the male.

The studies in cattle (Holmes and Ashmore, 1972; Cornforth *et al*, 1980, Spindler *et al.* 1980) and in sheep (Moody *et al.* 1980) listed in Table 11, are inconclusive and inconsistent in demonstrating a sex difference in fibre type morphology. The use of percentages for certain measurements did not allow estimation of the number of fibre types and their actual contribution in terms of area during growth. Also, if one fibre type increased in size significantly faster than another (Table 8) expressing the fibre type number as a percentage of total number of fibres within a certain area (Moody *et al.* 1980) would mean a decrease in percentage per unit area for the fibre type, although total number for each fibre type may be constant (Table 9).

The mechanisms by which differences and similarities in muscle growth are achieved is summarised in Fig. 21. At birth, males and females may start with the same WMA, but as they grow the neck muscles in males become bigger than female, and are hypertrophied in

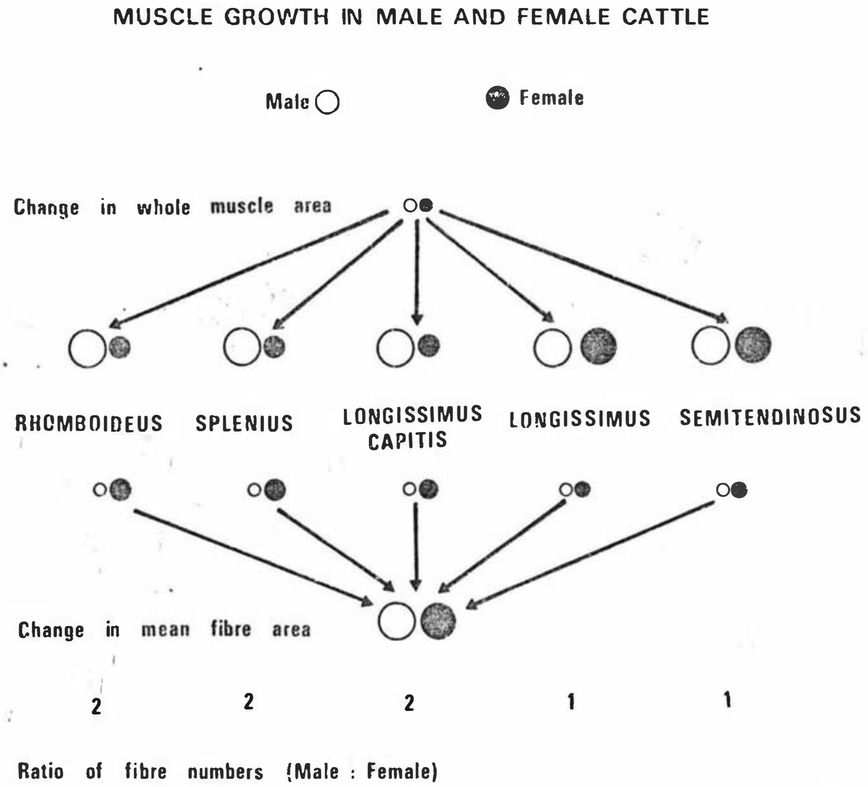


Figure 21: Diagrammatic summary of growth in five muscles in male and female Jersey cattle. Changes in muscle size and muscle fibre size is represented by whole muscle area and mean fibre area, respectively.

males at maturity. On the other hand, the growth changes in WMA do not differ between sexes in *mm. longissimus* and *semitendinosus*. This increase in muscle size is dependent on the total fibre number and the rate of increase in fibre size. Because the neck muscles in males have twice the number of fibres found in these muscles in females, the muscle fibres in males therefore do not need to grow faster than those in females to result in a faster growing muscle. However, in general, fibre growth is faster in males than females, especially in the case of the neck muscles. Although the fibres are smaller at birth in males than in females, they grow faster such that at heavier weights they may be equal or greater in size than that in females.

In conclusion, the basis of sexual dimorphism of overall muscle growth and muscle distribution in cattle and perhaps for all species is attributable to differences in antenatal development of fibre number, which determines the potential of a muscle to grow. Factors like nutrition, castration, hormones and usage determine the level to which the potential can be expressed and its rate of expression.

3.3 FAT GROWTH

3.3.1 RESULTS

The growth of fat in male and female Jersey cattle was investigated in relation to the amount of fat in a half carcass or amount of fat in a depot. Comparison between sexes was made at various levels of fatness. At the levels of fatness chosen, the approximate total side muscle plus bone (TSMB) weight and maturity were indicated (Table 13, 15, 16 and 17).

3.3.1.1 Relative growth of fat depots

The allometric equations relating fat depot weights to total side fat (TSF), for male and female cattle are given in Table 12a. The relative growth of subcutaneous fat (SCF), intermuscular fat (IMF) and perirenal fat (PRF)

Table 12: Double logarithmic regressions comparing the growth of fat depot weights and various subcutaneous and intermuscular fat group weights, in grammes, relative to total side fat (TSF) between 21 male and 18 female Jersey cattle, from birth to maturity.

	Male				Female		
Fat depot	Growth Ratio b_{Φ}	s_b	Constant	Sex Diff.	Growth Ratio b_{Φ}	s_b	Constant
(a) Subcutaneous	1.176**	.052	-1.678	+	1.324***	.034	-2.151
Intermuscular	1.061**	.019	-0.652	NS	1.098***	.018	-0.835
Perirenal	0.977	.058	-0.745	NS	1.097*	.039	-1.150
Channel	0.963	.052	-1.195	NS	0.997	.054	-1.328
Cavity	1.115	.081	-1.905	NS	1.295**	.097	-2.669
Cod or udder	1.053	.046	-1.140	+++	0.797***	.033	-0.098
Sternal	0.814***	.040	-0.919	NS	0.851*	.058	-1.077
Bone	0.735***	.043	0.006	NS	0.713***	.037	0.018
Spinal	0.500***	.060	-0.153	NS	0.564***	.069	-0.472
Fat group							
(b) Forequarter subcutaneous	1.456***	.117	-3.245	NS	1.479***	.060	-3.195
Hindquarter subcutaneous	1.107	.053	-1.594	NS	1.233***	.034	-2.003
Forequarter intermuscular	1.118***	.025	-1.071	NS	1.148***	.022	-1.243
Hindquarter intermuscular	0.975	.021	-0.761	NS	1.040	.029	-1.016
(c) Cutaneus trunci -tensor fasciae latae subcutaneous (SCF I)	1.079	.045	-1.823	NS	1.043	.055	-1.732
Medial pelvic limb subcutaneous (SCF II)	0.955	.060	-1.700	+	1.106*	.042	-2.187
(d) Axial intermuscular	1.201**	.060	-1.915	NS	1.313***	.042	-2.364
Extrinsic intermuscular	1.121**	.035	-1.564	NS	1.116**	.032	-1.603
Intercostal intermuscular	1.220**	.070	-2.325	NS	1.165**	.043	-2.201
Abdominal intermuscular	1.221***	.049	-2.166	++	1.488***	.063	-3.182
Sublumbar intermuscular	1.007	.044	-1.747	NS	1.003	.046	-1.769
Brachial intermuscular	0.970	.038	-1.445	NS	0.938	.036	-1.397
Antebrachial intermuscular	0.658***	.085	-1.048	NS	0.734***	.058	-1.480
Pelvic intermuscular	0.933*	.032	-0.893	NS	0.956	.030	-1.010
Crural intermuscular	0.873**	.033	-1.254	NS	0.938	.060	-1.561

Φ Regression coefficient b, standard error s_b.

* Values of b bearing this superscript are significantly ($P < 0.05$) different from 1.

\+ Significantly ($P < 0.05$) different in b between sexes.

depots is shown in Fig 22. In both sexes, SCF grew significantly (male: $P < 0.05$, female: $P < 0.001$) faster than IMF and PRF; IMF and PRF did not differ significantly ($P > 0.05$) in their growth ratios (b). Of the nine depots dissected, only SCF and cod or udder fat showed a sex difference in b. SCF grew significantly faster in females than males, while udder fat in females was significantly slower growing than cod fat in males.

Using the equations of Table 12a, the amount of fat in each depot was predicted (Table 13) for both sexes at 7.5 and 30.0 kg TSF, which as shown in Section 3.1 (Table 2), respectively, approximate to half mature and mature Jersey cattle of either sex. At the same fatness, females had less TSMB than males. In fact, a male and female of 7.5 and 30.0 kg TSF, respectively, each approximated to a TSMB of 70 kg.

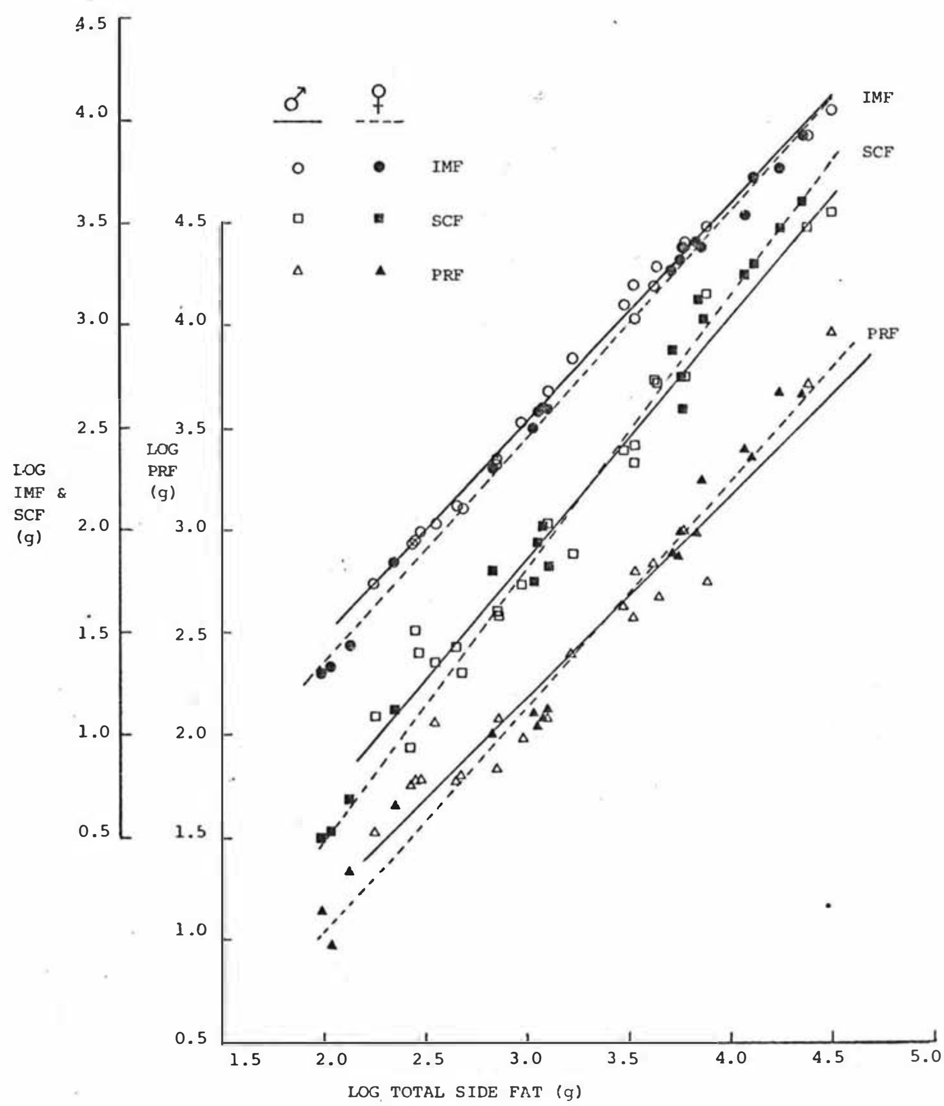


Figure 22: Allometric growth of intermuscular fat (IMF), subcutaneous fat (SCF) and perirenal fat (PRF) relative to total side fat (TSF), in male and female Jersey cattle.

Table 13: Predictions of the weights in grammes of the fat depots to show the partitioning of these depots at 7500 and 30000 grammes total side fat (TSF) in male and female Jersey cattle, using the equations of Table 12a.

	Half mature		Mature	
	Female	Male	Female	Male
+Approximate TSMB (g)	35000	70000	70000	140000
Total side fat	7500	7500	30000	30000
Subcutaneous fat	950a	760a	5980b	3870b
*Range	810 1120	600 960	4730 7560	2700 5530
Intermuscular fat	2630a	2880a	12000b	12500b
*Range	2420 2860	2650 3140	10700 13600	11000 14300
Perirenal fat	1260a	1100a	5770b	4260b
*Range	1050 1510	844 1430	4420 7550	2840 6380
Channel fat	343a	344a	1370b	1310b
*Range	267 440	272 435	947 1970	795 1870
Cavity fat	230a	260a	1390b	1220b
*Range	146 360	181 375	716 2690	697 2140
Cod or udder fat	978a	872a	2950b	3760b
*Range	839 1140	707 1080	2360 3700	2720 5180
Sternal fat	166a	172a	540b	530b
*Range	127 217	144 206	365 801	403 700
Bone fat	604a	715a	1620b	1980b
*Range	507 718	588 869	1260 2100	1470 2670
Spinal fat	51.7a	60.9a	113ab	122b
*Range	37.4 71.4	46.5 79.7	70.3 182	80.6 184

\+ The TSF weights of 7500 and 30000 grammes are within the predicted range of TSF weight obtained at the indicated weight of total side muscle plus bone (TSMB), given in Table 2.

* 95% confidence limits; probability of a value outside these limits < 0.05. Values of weight within each fat depot not followed by the same letter are outside each others confidence limits.

At the same TSF, males and females did not differ significantly in the amount of fat present in each depot (Table 13). Throughout the growth range (Fig. 22) in both sexes, the intermuscular depot was heaviest. For perirenal, subcutaneous and udder or cod fat, the order of importance based on the weight of fat present in the depot (Table 14) depended on the stage of fatness. At 7.5 kg TSF, the order in ranking was similar between sexes. However, because of the significant sex difference in the growth of SCF and cod or udder fat, there were differences in the ranking order at 30.0 kg TSF between males and females, especially for SCF. This difference was considered small and in general the partitioning of fat into the various fat depots followed similar patterns in both sexes, when compared at similar fatness.

At approximately the same TSMB of 70 kg, females had more TSF and significantly more fat in each depot than males, except in the case of spinal fat (Table 13). The partitioning of fat differed between sexes at this stage of growth because in males, the PRF and cod depot were bigger contributers to TSF than the SCF depot, while in females the SCF was the heavier depot, after the IMF depot (Table 14).

Table 14: Depots are ranked in decreasing order, according to the weight of fat predicted in Table 13 at 7500 and 30000 grammes total side fat (TSF). Within each column, depots followed by the same number are within each others confidence limits in the predicted amount of fat given in Table 13.

†Approximate TSMB (g)							
35000		70000		70000		140000	
7500 TSF		7500 TSF		30000 TSF		30000 TSF	
Female		Male		Female		Male	
Intermuscular	1	Intermuscular	1	Intermuscular	1	Intermuscular	1
Perirenal	2	Perirenal	2	Subcutaneous	2	Perirenal	2
Udder	3	Cod	3	Perirenal	2	Subcutaneous	2
Subcutaneous	3	Subcutaneous	3	Udder	3	Cod	2
Bone	4	Bone	3	Bone	4	Bone	3
Channel	5	Channel	4	Cavity	4,5	Channel	3
Cavity	5	Cavity	4,5	Channel	4	Cavity	3,4
Sternal	6	Sternal	5	Sternal	5	Sternal	4
Spinal	7	Spinal	6	Spinal	6	Spinal	5

† The TSF weights of 7500 and 30000 grammes are within the predicted range of TSF weights obtained at the indicated weight of total side muscle plus bone (TSMB), given in Table 2.

3.3.1.2 Subcutaneous and intermuscular fat in forequarter and hindquarter

The allometric growth equations for SCF and IMF in the forequarter (FQ) and hindquarter (HQ), for male and female Jersey cattle are shown in Table 12b. Between sexes, the *b* value for each of the *y* components was higher in females than males and in particular, that of HQSCF. For both sexes, each depot grew significantly ($P < 0.01$) faster in the FQ than in the HQ.

Predictions of the amount of SCF and IMF in the FQ and HQ at two levels of fatness are given in Table 15. The distribution of these two depots into FQ and HQ was similar in amount for both sexes, when compared at the same TSF. At approximately the same TSMB, females had more fat than males for each of the predictions. In both sexes and throughout growth, the order in terms of amount of fat remained the same, namely, FQIMF > HQIMF > HQSCF > FQSCF.

3.3.1.3 Anatomical distribution of subcutaneous fat

Subcutaneous fat (SCF) was dissected from regions 1 to 6 in the FQ and regions I to VI in the HQ, as described in Section 2.4.1 and shown in Fig. 2. In Jersey cattle, SCF did not appear at birth as a single continuous fat layer in the carcass. Instead, SCF concentrated in certain areas within most of the regions and appeared to grow by extending the boundaries of these areas. Hence, SCF is variable in thickness on the carcass. Fig. 23 illustrates the growth and distribution of SCF. In regions IV, 4 and 5, fat growth is diffuse rather than arising from a particular area within the region. Especially in region 5, fat was usually found as an even continuous layer.

Only in the HQ regions I and II was dissectible SCF present at all stages of growth, from birth to maturity. The allometric growth equations for fat from these regions (SCF I and II) are given in Table 12c. SCF II was significantly faster growing in females than in males. SCF I, which is the fat depot used to represent subcutaneous fat for histology and chemical analysis, did not differ significantly in *b* values between sexes.

Table 15: Predictions of the weights in grammes of forequarter (FQ) and hindquarter (HQ) subcutaneous fat (SCF) and intermuscular fat (IMF) to show the distribution of these depots at 7500 and 30000 grammes total side fat (TSF), in male and female Jersey cattle, using the equations of Table 12b.

	Half mature		Mature	
	Female	Male	Female	Male
† Approximate TSMB (g)	35000	70000	70000	140000
TSF	7500	7500	30000	30000
FQSCF	344a	249a	2671b	1878b
*Range	260	147	1775	837
	454	422	4019	4216
HQSCF	594a	497a	3280b	2307b
*Range	506	392	2594	1600
	697	631	4149	3327
FQIMF	1605a	1825a	7883b	8598b
*Range	1447	1633	6770	7246
	1780	2040	9179	10202
HQIMF	1033a	1040a	4367b	4020b
*Range	904	945	3594	3471
	1179	1144	5306	4655

† The TSF weights of 7500 and 30000 grammes are within the predicted range of TSF weight obtained at the indicated weight of total side muscle plus bone (TSMB), given in Table 2.

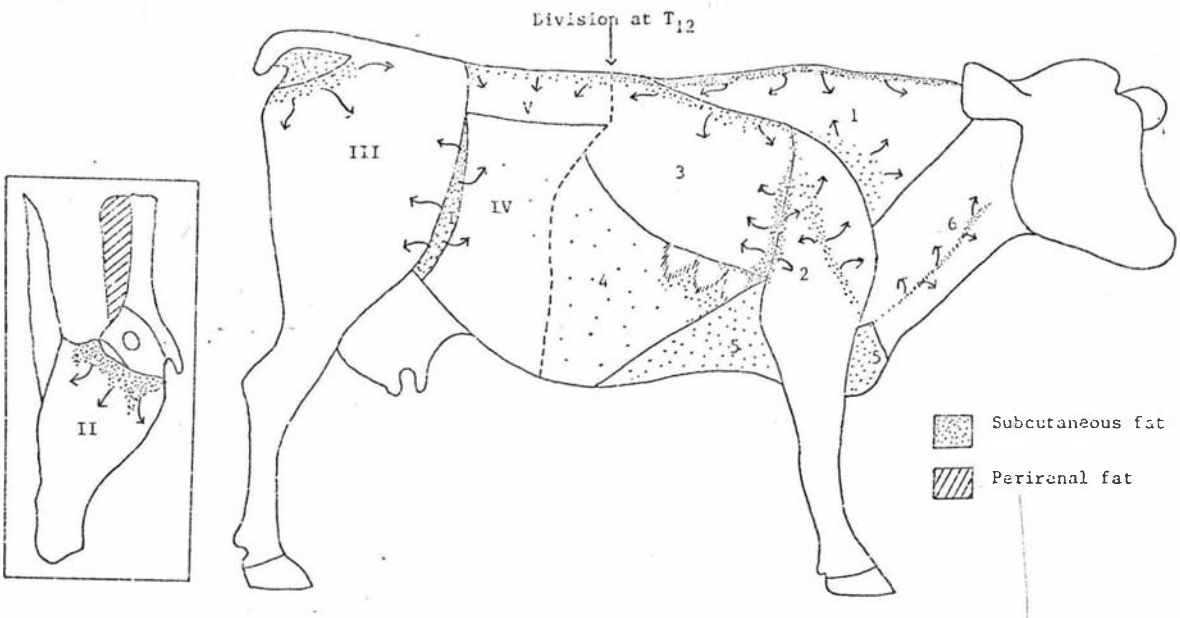
* 95% confidence limits; probability of a value outside these limits < 0.05. Values of weight within each fat depot not followed by the same letter are outside each others confidence limits.

Table 16: Predictions of the weight in grammes of subcutaneous fat between *mm. cutaneus trunci* and *tensor fasiae latae* (SCF I) and that on the medial aspect of the pelvic limb (SCF II), to show the distribution of this depot at 7500 and 30000 grammes total side fat (TSF) in male and female Jersey cattle, using the equations of Table 12c.

	Half mature		Mature	
	Female	Male	Female	Male
†Approximate TSMB (g)	35000	70000	70000	140000
TSF	7500	7500	30000	30000
SCF I	204a	229a	866b	1020b
*Range	158	187	594	750
	270	279	1263	1389
SCF II	126a	100a	582b	376b
*Range	103	76.2	437	248
	153	132	774	572

†The TSF weights of 7500 and 30000 grammes are within the predicted range of TSF weight obtained at the indicated weight of total side muscle plus bone (TSMB), given in Table 2.

*95% confidence limits; probability of a value outside these limits < 0.05. Values of weight within each fat depot not followed by the same letter are outside each others confidence limts.



Hindquarter subcutaneous fat		Forequarter subcutaneous fat	
I	Cutaneus trunci - tensor fascia latae	1.	Trapezius
II	Medial pelvic limb	2	Thoracic limb
III	Lateral pelvic limb	3	Latissimus dorsi
IV	Abdominal	4	Cutaneus trunci - abdominal
V	Longissimus	5	Pectoral
VI	Perianal	6	Neck

Figure 23: Distribution and growth of subcutaneous fat from areas within the anatomical regions 1 to 6 and I to VI.

At the same TSF (Table 16), males had more SCF I but less SCF II than females, though not significantly so. However, at approximately the same TSMB, females had significantly more fat in both regions.

In the other regions, SCF was not always present in either sex. Therefore, for these regions, double logarithmic analysis was not carried out. However, it was observed that after SCF I and SCF II, fat in region VI (perianal) was present in a more readily dissectable amount than the other regions, at low TSF values. There was generally very little fat in region 6 (neck) during growth.

3.3.1.4 Distribution of intermuscular fat

The allometric growth equations of nine IMF groups relative to TSF are given in Table 12d. Only IMF from the abdominal muscle group showed significant difference in growth ratio between sexes. At the same TSF (Table 17), there were no significant differences between sexes in the amount of IMF in each of the groups. The largest difference in amount between sexes was observed in the abdominal IMF.

Table 17: Predictions of the weights in grammes of intermuscular fat from various muscle groups, to show the distribution of this depot at 7500 and 30000 grammes total side fat (TSF) in male and female Jersey cattle, using the equations of Table 12d.

	Half mature		Mature	
	Female	Male	Female	Male
† Approximate TSMB (g)	35000	70000	70000	140000
TSF	7500	7500	30000	30000
AXIAL	530a	549a	3269b	2903b
*Range	436	418	2455	1912
	643	721	4353	4410
EXTRINSIC	527a	602a	2474b	2850b
*Range	453	515	1985	2240
	612	705	3084	3624
INTERCOSTAL	206a	253a	1035b	1371b
*Range	169	184	771	842
	251	347	1388	2234
ABDOMINAL	384a	368a	3019b	1997b
*Range	287	294	1969	1420
	513	459	4624	2809
SUBLUMBAR	131a	143a	527b	577b
*Range	106	117	385	425
	162	174	720	784
BRACHIAL	173a	206a	635b	790b
*Range	146	174	495	609
	205	244	814	1026
ANTEBRACHIAL	23.1a	31.8ab	64.0b	79.0b
*Range	17.7	21.6	43.2	43.9
	30.2	46.6	94.9	142
PELVIC	495a	528a	1862b	1924b
*Range	431	457	1520	1542
	568	610	2281	2400
CRURAL	119a	135a	435b	451b
*Range	89.6	116	288	358
	157	156	656	569

† The TSF weights of 7500 and 30000 grammes are within the predicted range of TSF weight obtained at the indicated weight of total side muscle plus bone (TSMB), given in Table 2.

* 95% confidence limits; probability of a value outside these limits < 0.05. Values of weight within each fat depot not followed by the same letter are outside each others confidence limits.

At approximately the same TSMB, a significant difference between sexes was observed in the amount of IMF for each of the groups with the exception of the antebrachial group.

3.3.1.5 Adipose tissue, lipid and adipocyte growth in three fat depots

The results of the growth of subcutaneous, intermuscular and perirenal fat in terms of their total lipid content (LIPT) and lipid content per adipocyte (LIPA) are given in Tables 18 to 20 and Figs 24 to 26. The estimated number of adipocytes (NA) at various weights of fat in each depot was obtained by dividing predicted values of LIPT by LIPA (Table 20). Fig. 27 illustrates the morphology and adipocyte size changes in the subcutaneous fat of males at birth and maturity.

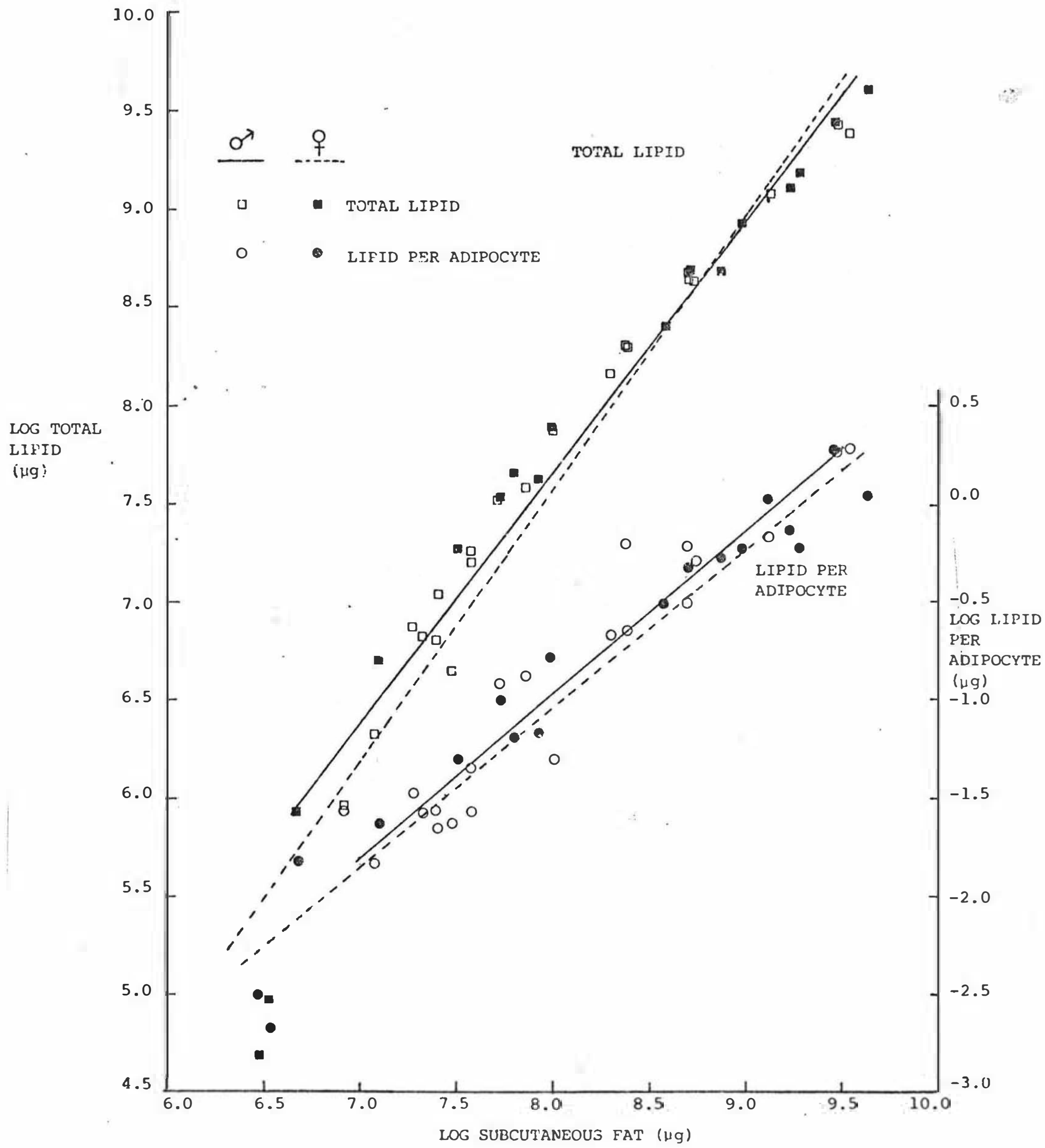


Figure 24: Allometric growth change in the weight (µg) of total lipid and lipid per adipocyte relative to the weight of subcutaneous fat depot (µg), in male and female Jersey cattle.

In Table 18, where x is LIPA and y is LIPT, a growth ratio (b) significantly greater than 1 suggests an increase in NA; this is observed for all three depots in females, and for subcutaneous and intermuscular depots in males. In common to both sexes, the b value is highest for the subcutaneous, intermediate for the intermuscular and lowest for the perirenal fat depot. This suggests that subcutaneous fat has the fastest rate of increase in NA and perirenal fat the slowest. However, females have higher values of b than males for all three depots and significantly so for subcutaneous and intermuscular fat. This suggests a faster rate of increase in NA in females than males for each of the depots.

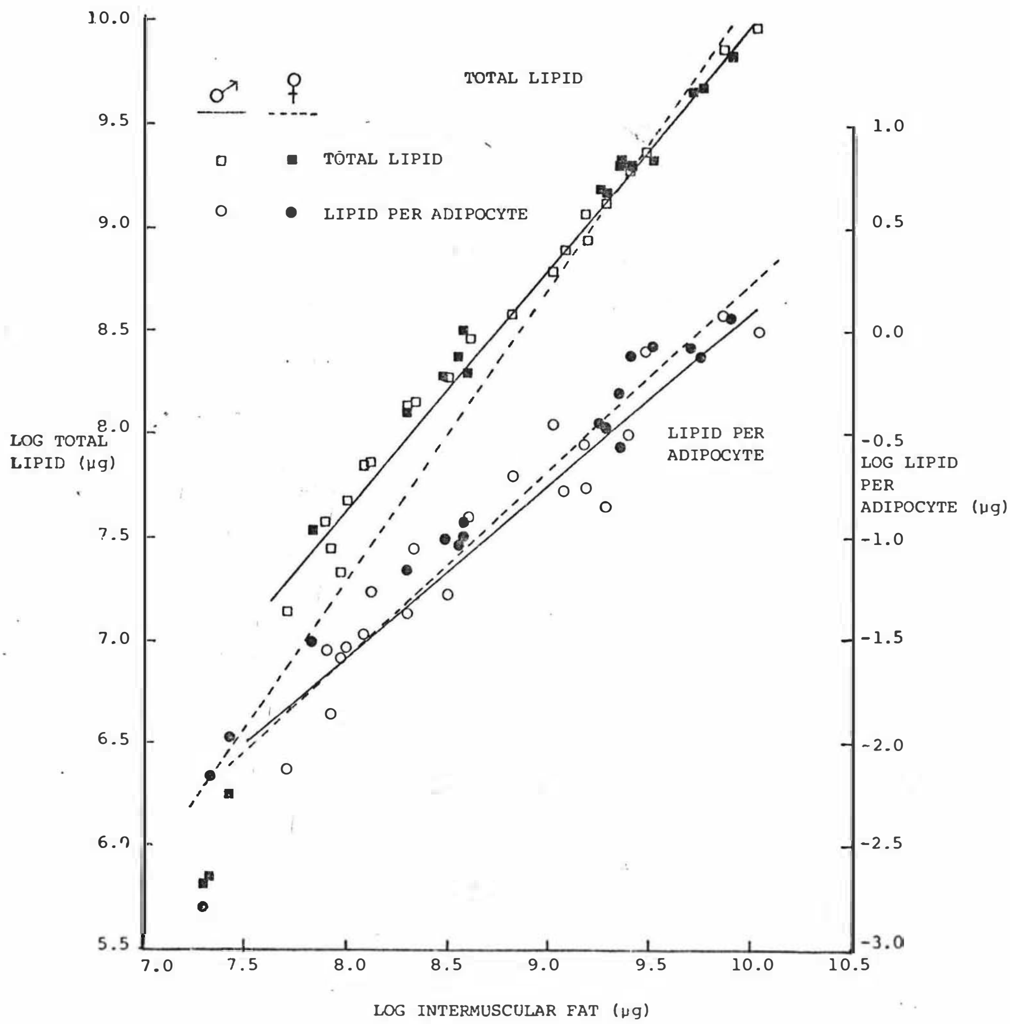


Figure 25: Allometric growth change in the weight (μg) of total lipid and lipid per adipocyte relative to the weight of intermuscular fat depot (μg), in male and female Jersey cattle.

In Table 19a, y is LIPT and x is the wet weight of the depot. A b value significantly greater than 1, as is observed for both sexes in the regressions of all three depots, suggests that lipid is accumulated at a faster rate than non-lipid components. Between sexes, the b values for all three depots is higher in females than males.

In Table 19b, where y is LIPA and x is the wet weight of the depot, a b value less than 1 indicates that the increase in size of the adipocyte is smaller than would be expected if individual adipocyte lipid accumulation accounted for all the weight increase of the depot. The increase in LIPA is slowest for subcutaneous fat and fastest for perirenal fat, in both sexes. There are no significant sex differences in b values of LIPA relative to weight of the depot, for all three depots, indicating that the increase in adipocyte lipid is similar between sexes.

Table 18: Double logarithmic regressions relating the change in weight (μg) of lipid content per adipocyte (LIPA) to total lipid content (LIPT) of each of subcutaneous, intermuscular and perirenal fat depot, in male and female Jersey cattle.

Variable x = LIPA y = LIPT

	Male				Female		
Fat depot	Growth Ratio $b\Phi$	s_b	Constant	Sex Diff.	Growth Ratio $b\Phi$	s_b	Constant
Subcutaneous	1.412**a	.108	9.056	†	1.680***a	.069	9.305
Intermuscular	1.304**a	.084	9.757	†	1.582***a	.079	9.835
Perirenal	1.004b	.077	9.168	NS	1.168***b	.035	9.217

Φ Regression coefficient b, standard error s_b. Values of b within each sex not followed by the same letter are significantly ($P < 0.05$) different between depots.

* Values of b bearing this superscript are significantly ($P < 0.05$) different from 1.

† Significantly ($P < 0.05$) different in b between sexes.

Table 19: Double logarithmic regressions relating the change in weight (μg) of total lipid content (LIPT) and lipid content per adipocyte (LIPA) to the weight of each of subcutaneous, intermuscular and perirenal fat depot, in male and female Jersey cattle.

(a) Variable x = weight of depot y = LIPT

	Male				Female		
Fat depot	Growth Ratio $b\Phi$	s_b	Constant	Sex Diff.	Growth Ratio $b\Phi$	s_b	Constant
Subcutaneous	1.282***a	.050	-2.573	NS	1.383***a	.079	-3.488
Intermuscular	1.180***ab	.033	-1.809	††	1.472***a	.080	-4.473
Perirenal	1.109***b	.020	-1.032	NS	1.211**b	.054	-1.952

(b) Variable x = weight of depot y = LIPA

	Male				Female		
Fat Depot	Growth Ratio $b\Phi$	s_b	Constant	Sex Diff.	Growth Ratio $b\Phi$	s_b	Constant
Subcutaneous	.835*a	.059	-7.648	NS	.809**a	.049	-7.503
Intermuscular	.838*a	.060	-8.284	NS	.908 ab	.053	-8.851
Perirenal	.979 a	.087	-9.112	NS	1.032 b	.042	-9.519

Φ Regression coefficient b, standard error s_b. Values of b within each sex not followed by the same letter are significantly ($P < 0.05$) different between depots.

* Values of b bearing this superscript are significantly ($P < 0.05$) different from 1.

† Significantly ($P < 0.05$) different in b between sexes.

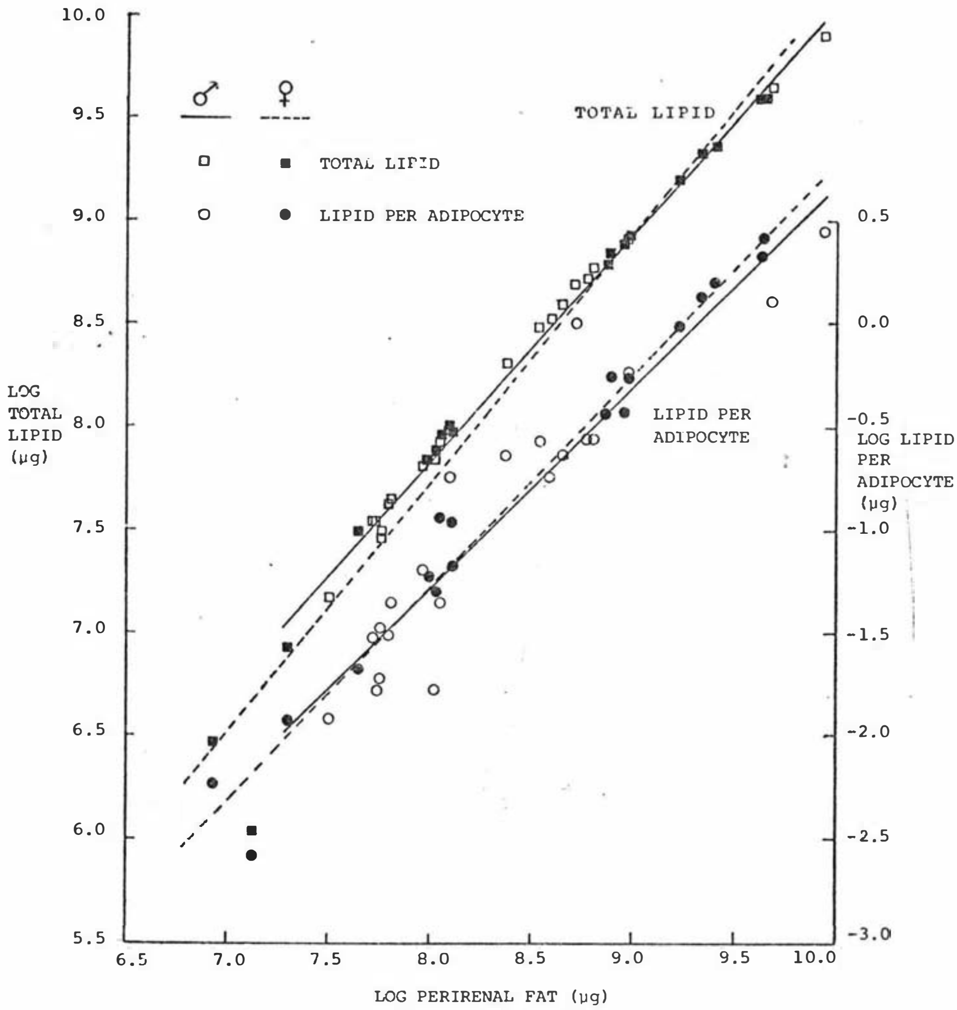


Figure 26: Allometric growth change in the weight (μg) of total lipid and lipid per adipocyte relative to the weight of perirenal fat depot (μg), in male and female Jersey cattle.

When the b value for LIPA of each of the depots in Table 19b is compared to that for LIPT in Table 19a, a significant difference in b values suggests an increase in NA. Significant ($P < 0.05$) differences in b values were observed for all three depots in females and for two depots, subcutaneous and intermuscular, in males. This is similar to the observations made from Table 18.

Table 20 contains predictions of LIPT, LIPA and NA for each depot, at three depot weights, covering birth to maturity. The two heavier depot weights were chosen on the basis of Table 13, approximating to half mature and mature male and female Jersey cattle. A half mature male and a mature female have approximately the same TSMB of 70 kg (Table 2).

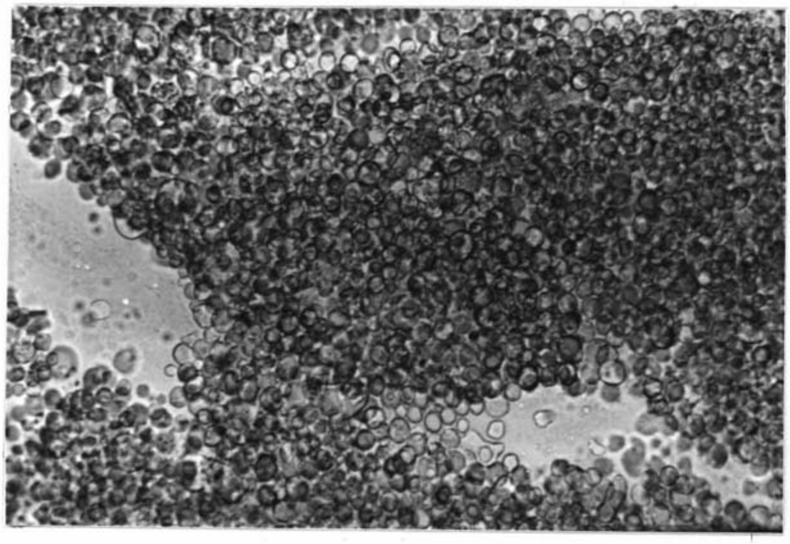
Table 20: Predictions of total lipid content (LIPT) and lipid content per adipocyte (LIPA) and estimated number of adipocytes (NA), at various depot weights for each of subcutaneous, intermuscular and perirenal fat depots, in male and female Jersey cattle, using the equations of Table 19.

	Birth		Half mature		Mature	
	Female	Male	Female	Male	Female	Male
Subcutaneous fat (g)	10	10	750	†750	†5980	5980
LIPT (μg)	1.55×10^6a	2.51×10^6a	6.11×10^8b	6.35×10^8b	1.08×10^{10}c	9.14×10^9c
*Range	0.85×10^6	1.84×10^6	3.70×10^8	4.85×10^8	5.25×10^9	5.80×10^9
	2.85×10^6	3.43×10^6	1.01×10^9	8.32×10^8	2.23×10^{10}	1.44×10^{10}
LIPA (μg)	.015a	.016a	.475b	.579b	2.55c	3.28c
*Range	.010	.011	.348	.420	1.62	1.94
	.021	.023	.648	.797	4.00	5.61
NA ($\times 10^9$)	.107a	.160a	1.29b	1.10b	4.24c	2.79bc
*Range	.052	.099	.713	.722	1.85	1.38
	.218	.260	2.32	1.67	10.2	5.64
Intermuscular fat (g)	50	50	2755	†2755	†12050	12050
LIPT (μg)	7.24×10^6a	1.91×10^7b	2.65×10^9c	2.14×10^9c	2.30×10^{10}d	1.22×10^{10}d
*Range	4.27×10^6	1.57×10^7	1.75×10^9	1.83×10^9	1.20×10^{10}	9.58×10^9
	1.23×10^7	2.31×10^7	4.01×10^9	2.50×10^9	4.20×10^{10}	1.55×10^{10}
LIPA (μg)	.014a	.015a	.525b	.423b	2.01c	1.46c
*Range	.010	.010	.398	.318	1.34	.939
	.019	.021	.694	.564	3.01	2.26
NA ($\times 10^9$)	.521a	1.29a	5.04b	5.05b	11.6b	8.37b
*Range	.270	.870	3.05	3.64	5.59	5.07
	.984	1.93	8.32	7.01	24.0	13.8
Perirenal fat (g)	32	32	1180	†1180	†5773	5773
LIPT (μg)	1.36×10^7a	1.93×10^7a	1.08×10^9b	1.07×10^9b	7.40×10^9c	6.21×10^9c
*Range	9.87×10^6	1.74×10^7	8.21×10^8	9.75×10^8	4.91×10^9	5.37×10^9
	1.89×10^7	2.13×10^7	1.43×10^9	1.17×10^9	1.15×10^{10}	7.20×10^9
LIPA (μg)	.016a	.017a	.697a	.588b	3.57c	2.78c
*Range	.013	.011	.563	.392	2.60	1.44
	.022	.027	.864	.883	4.91	5.39
NA ($\times 10^9$)	.817a	1.13ab	1.55ab	1.82ab	2.07b	2.23ab
*Range	.530	.710	1.09	1.20	1.31	1.13
	1.25	1.79	2.20	2.76	3.28	4.40

† These depot weights are within the predicted range of values for each of the depots, obtained at total side fat weights representing male and female Jersey cattle of approximately 70 kg total side muscle plus bone, as shown in Table 13.

* 95% confidence limits; probability of a value outside these limits < 0.05. Values of weights and number within each fat depot and row, not followed by the same letter are outside each others confidence limits.

Birth



Maturity

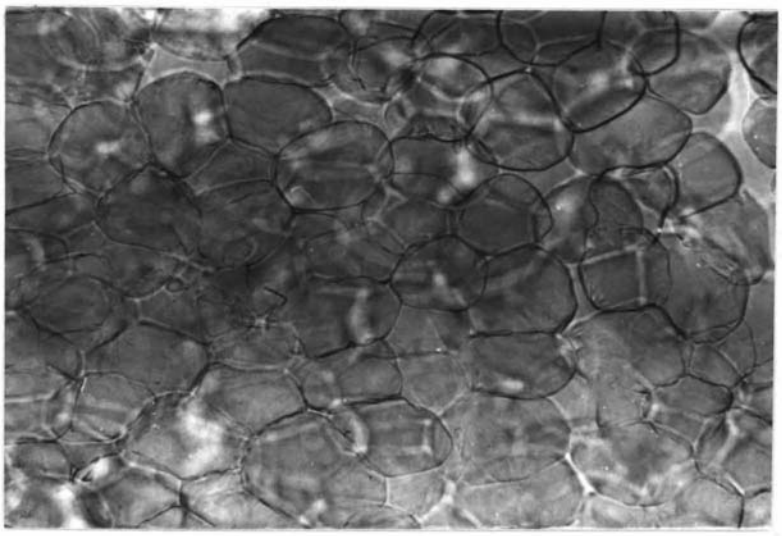


Figure 27: Photomicrographs of 50 μm and 250 μm thick sections (magnification X 190) of subcutaneous fat at birth and at maturity, respectively, of male Jersey cattle.

At the same depot weight, males and females do not differ significantly in LIPT, LIPA and NA, for each of the depots. This suggests that adipose tissue growth in male and female cattle follow similar cellular patterns when related to the same level of depot fatness.

However, when compared at approximately the same TSMB of 70 kg, females have significantly more LIPT and LIPA than males for all the three depots. Females also have greater NA than males, particularly for the subcutaneous and intermuscular depot, and are significantly different in the case of subcutaneous depot. Hence, at the same TSMB, females have more depot fat, bigger adipocytes and more adipocytes than males.

3.3.2 DISCUSSION

3.3.2.1 Sources of error and assumptions

In the younger cattle of this study, low levels of dissectible fat were encountered; there was an absence of dissectible subcutaneous fat from many regions on the carcasses of these animals. Another problem was that at birth, adipose tissue boundaries within a connective tissue matrix were poorly defined because of low lipid content. This introduces not only dissection errors but also errors during chemical analysis for lipid. Figs. 24 to 26 illustrate the variation in LIPT and LIPA; the variation is more noticeable for subcutaneous and intermuscular fat than perirenal fat, which shows an early antenatal development of well defined lobules (Bell, 1909).

TSF weight or weight of depot is used as a basis of comparison between sexes, in order to reduce variation which may arise from environmental factors disproportionately affecting the growth of fat free carcass components and fat. This basis of comparison will enable the determination of the extent to which fat growth conforms to an organised pattern.

The use of small samples of adipose tissue for chemical analysis and histology, to represent the whole of a depot, is a source of error. The b value for SCF relative to TSF is significantly higher in females than males (Table 12a). However, the *b* value of SCF I (cutaneus trunci-tensor fasciae latae), from which samples were taken to represent SCF, is lower in females than males, although not significantly so (Table 12c). Furthermore, SCF I is significantly ($P < 0.001$) slower growing than total SCF in females, although not significantly ($P > 0.05$) different in males (Table 12a, c). A slower growing adipose tissue suggests a slower rate of lipid accumulation. Therefore, samples of SCF I may underestimate LIPT present in SCF depot, especially at higher SCF weights, and significantly so for females. The underestimation of LIPT in females may explain the results in Table 19a, which shows that lipid is accumulated at a slower rate in the SCF depot than the IMF depot, even though Table 12a indicates that SCF is a faster growing depot than IMF.

As a consequence to LIPT underestimation, NA in the SCF depot will also be underestimated for females. If the underestimation for LIPT is accounted for, then sex differences in which females have a greater NA than males (Table 20), will be enhanced for the SCF depot.

Adipose tissue samples were obtained from the brachial muscle group (Table 12d) to represent the IMF depot. The *b* values of IMF and brachial group relative to TSF, do not differ significantly between sexes. Because the brachial group is significantly ($P < 0.05$) slower growing than IMF in both sexes, the underestimation of LIPT, and therefore NA, is assumed to affect both sexes equally. If there is a sex difference in underestimation, it is more likely to increase the difference between males and females.

In spite of the errors incurred from sampling procedures, the conclusions should not be affected, because the present results are used comparatively between two sexes which have been treated in the same manner.

In this study an increase in NA must be interpreted as an increase in detectable adipocytes using histometric methods. Compared to the Coulter counting of osmium-fixed cells, a histometric method permits cells with a diameter below 25 μm to be detected (Sjöström, Björntorp and Vrána, 1971). In the experiment on foetal sheep (Broad, Davies and Tan, 1980) where the same histometric method was used, adipocytes of about 5 μm diameter could be detected. The adipocyte size range is therefore from 5 to 250 μm which covers a 50-fold increase.

3.3.2.2 <u>The partitioning and distribution of carcass fat</u>

In general, at the same TSF, male and female Jersey cattle are similar in the partitioning of TSF and in the distribution of the SCF and IMF depots (Tables 13 to 17), from birth to maturity. Results comparing males and females of Shorthorn-cross (Berg *et al.* 1979) and of Hereford and "Dairy Synthetic" (Jones, Price and Berg, 1980) cattle breeds also support this conclusion. Dijkstra (1979), using Dutch cattle breeds, showed that at equal fat percentage in the carcass, females have relatively less SCF and more IMF than males. Because comparison was made at equal fat percentage in the carcass, males and females can be expected to have differed in their total fat weight and maturity. In sheep (Vezinhet and Prud'hon, 1975; Gaili, 1978) the partitioning and distribution of fat are similar in males and females when considered relative to the weight of total fat or depot fat.

Differences between male and female cattle in the patterns of fattening are a consequence of differences in rate of fat deposition on a particular site (Table 12). Consequently, when compared at the same body size such as TSMB, the partitioning (Tables 13 & 14) and distribution (Tables 15 to 17) of fat differ in amounts between sexes, with females having more fat than males. However, the order of importance in terms of amount of fat for the fat depots and fat groups, within each sex (Table 14), show few differences between sexes. Hence, fat growth appears to occur in an ordered fashion. Further evidence will be given in the next section 3.3.2.3 on the distribution of SCF.

Common to both male and female Jersey cattle, IMF is the largest depot and SCF is the fastest growing depot, from birth to maturity. That IMF is the largest depot was also observed by Johnson, Butterfield and Pryor (1972), Kempster, Cuthbertson and Harrington (1976), Berg *et al.* (1979) and Dijkstra (1979). Johnson *et al.* (1972) noted a greater increase in the proportion of SCF than IMF, between two postnatal weight ranges, even though the linear regression equations encompassing antenatal and postnatal fat growth indicated that IMF is the fastest growing depot.

Nevertheless, re-inspection of their data by plotting on double logarithmic coordinates suggests that SCF depot is the fastest growing depot. This conclusion was also reached by Davies and Pryor (1977) and is consistent with the general findings that SCF contributes increasingly more than do the other depots in TSF as the animal grows (Berg and Butterfield 1976).

Kempster, Cuthbertson and Harrington (1976) noted that there were variations in fat distribution between fifteen breeds of cattle. Their results showed that SCF was slower growing than perinephric and retroperitoneal fat in four cattle breeds. Berg, Anderson and Liboriussen (1978c) observed small but significant sire effects on eight cattle breeds, in the amount of fat in each joint at a standard amount of total fat in the carcass. Hence, a sex comparison should preferably be carried out within one breed. The results of Jones *et al.* (1980) pooled the results from two breeds for a male and female comparison.

3.3.2.3 Subcutaneous fat distribution

Fig. 23 defines areas on the carcass in which subcutaneous fat first appears. These areas represent centres of subcutaneous fat growth; each of these subcutaneous 'growth centres' characterises the growth of the region delineated, by the rate and amount of fat deposited.

The concept of subcutaneous growth centres where fat concentrates and from which fat spreads, may explain the uneven distribution of subcutaneous fat ('patchy fat') observed in carcasses in the higher fat classes (Meat and Livestock Commission, 1975) and which may be a source of variation between breeds (Kempster, Avis and Smith, 1976). The present anatomical dissection of subcutaneous fat into regions is more accurate than jointing methods and may be useful for the purpose of defining areas of 'patchy fat'.

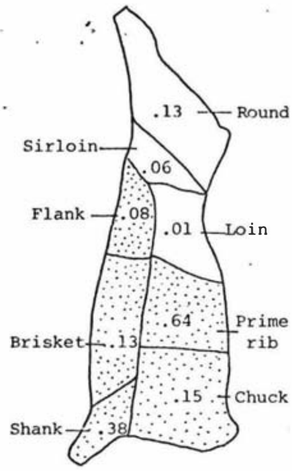
Cod or udder fat was dissected in the present study as a separate depot from SCF, although it could also be considered as a special form of SCF. The significantly lower b value of this depot in females than males (Table 12a) illustrates the presence of regional differences between sexes in the rate of fat deposition on the carcass surface. At birth, there was more cod or udder fat than SCF, while at maturity it constituted about half as much weight as SCF in females and an amount about equal to that of SCF in males (Table 13). If this depot were incorporated into SCF, this would lower the *b* value for SCF relative to TSF, in females. This may explain similar *b* values for SCF between Shorthorn-cross heifers and bulls (Berg *et al.* 1979), while a significant difference in *b* values for SCF was observed between male and female Jersey cattle. The differences in the results of these studies could also be due to breed.

Results of the joint dissection on 12 bulls and 12 heifers of two breed types Hereford and 'Dairy Synthetic' (Jones *et al.* 1980) are summarised in Fig. 28. In this study, sexes differ in the rate of SCF deposition in various cuts. This is further emphasised by ranking the growth ratios for the cuts for each sex (Fig. 28a); the order of ranking differs between sexes. Fig. 28b shows that in terms of amount of SCF in the cut, adjusted to a standard total side fat weight, sexes appear similar in their distribution of fat. The ranking order differed for the 'loin' and 'round', where heifers had respectively, more and less fat than bulls. Hence, sexes differ in the rate of subcutaneous fat deposition in various cuts but do not differ in the pattern of distribution when compared at the same TSF. This is also the general conclusion of section 3.3.2.2.

3.3.2.4 Adipose tissue growth in male and female cattle

That an increase in size and an increase in number of adipocytes, both contribute to adipose tissue growth, has been shown for meat animals (Anderson, 1972; Allen, 1976; Allen *et al.* 1976; Hood, 1977) and for humans (Brook , 1978; Knittle, 1978; Bulfer and Allen, 1979; Kirtland and Gurr, 1979). However, males and females may differ in the extent to which each of the processes is involved for various fat depots. This effect of sex on adipose tissue growth has not been investigated in the previous studies of fat growth in cattle (Hood and Allen, 1973, Enser and Wood, 1978; Schön, 1978; Truscott, Wood and Denny, 1980), sheep (Haugebak, Hedrick and Asplund, 1974; Hood and Thornton, 1979; Broad, Davies and Tan, 1980) and pigs (Lee, Kauffman and Grummer, 1973 a & b; Wood, Enser and Restall, 1975, 1978; Enser *et al.* 1976).

(a) Growth ratio *b* for subcutaneous fat in a cut relative to total side fat. The difference in *b* values between sexes are indicated in the figure.

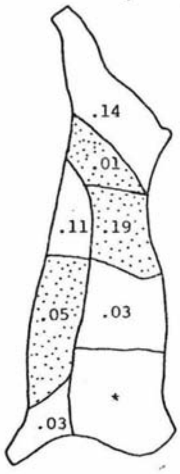


Female Cut	*b*	Male Cut	*b*
Prime rib	1.88	Loin	1.37
Loin	1.36	Prime rib	1.24
Shank	1.36	Chuck	1.13
Chuck	1.28	Sirloin	1.06
Flank	1.17	Flank	0.99
Brisket	1.08	Shank	0.98
Sirloin	1.00	Brisket	0.95
Round	0.81	Round	0.94

[stippled box] Cuts whose *b* values are higher in females than males.

[open box] Cuts whose *b* values are lower in females than males.

(b) Weight of subcutaneous fat (kg) in each cut adjusted to the mean of total side fat weight of 18.48 kg. The difference in weight between sexes are indicated in the figure.



Female Cut		Male Cut	
Flank	1.73	Flank	1.84
Loin	1.00	Round	1.13
Round	0.99	Loin	0.81
Brisket	0.79	Brisket	0.72
Prime rib	0.68	Prime rib	0.71
(Chuck	0.66	Chuck	1.62)*
Sirloin	0.29	Sirloin	0.28
Shank	0.20	Shank	0.23

* The value of 1.62 kg given for bulls appears unrealistically high. Therefore differences are not shown.

[stippled box] Cuts where amount of subcutaneous fat is higher in females than males.

[open box] Cuts where amount of subcutaneous fat is lower in males than females.

Figure 28: Comparison between male and female Hereford and "Dairy Synthetic" cattle breeds (Jones, Price and Berg, 1980) in the rate of subcutaneous fat distribution and amount of subcutaneous fat in each cut.

The present study examines the change in number and size of adipocytes for subcutaneous, intermuscular and perirenal depots in terms of

a) the rate of increase in number (Table 18);

b) the rate of increase in size (Table 19b); and

c) the extent of these increases from birth to maturity (Table 20).

The basis of comparison in adipose cellularity between sexes is the weight of the depot. The weights of each depot at which predictions in Table 20 were carried out, were chosen to represent three stages of growth, birth, half maturity and maturity. A half mature male and a fully mature female have approximately the same TSMB.

Adipose tissue growth in all three depots of both sexes, from birth to maturity, is characterised by a greater increase in size of adipocyte (LIPA) than in the increase in NA (Table 20). While adipocyte enlargement is the predominant feature of adipose tissue growth, results suggest that differences between male and female cattle in adipose tissue growth are due to differences in the rate of increase in the number of adipocytes. Evidence of this is discussed below for each depot.

The subcutaneous depot is significantly faster growing in females than males (Table 12a). This sex difference cannot be explained by a significantly faster rate of increase in adipocyte size because the rate of increase in LIPA relative to the depot weight is slower in females than males (Table 19b). On the other hand, the *b* value for LIPT relative to LIPA is significantly higher in females than males (Table 18), suggesting therefore a greater rate of increase in NA in females than in males. Also, Table 20 indicates that the increase in size, from birth to maturity, was smaller in females (about 170-fold) than in males (about 200-fold), while the increase in NA is greater in females (40-fold) than in males (17-fold). Thus, the faster and greater increase in NA must have more than compensated for the slower and smaller increase in size of the adipocyte, in order to account for the overall effect of a significantly faster growing subcutaneous fat depot in females than in males.

In the case of the intermuscular depot, the adipocyte size increase from birth to maturity was greater in females (140-fold) than in males (100-fold) (Table 20). However, the rate of increase in adipocyte size, although faster in females than males, is not significantly different between sexes (Table 19b). On the other hand, Table 18 indicates that the increase in NA is significantly faster in females than males. Therefore of significance is the observation, from birth to maturity, of a 22-fold increase in NA in females compared to only a 7-fold increase in males.

Perirenal adipose tissue cellularity appears similar in both sexes. The rate of increase in size (Table 19b) and number of adipocytes (Table 18) is not significantly different between sexes, although faster in females than in males. The increase from birth to maturity in number of adipocytes is similar in both sexes (about two-fold). Hence the increase in the size of adipocytes in females (210-fold) and in males (163-fold) is the main factor contributing to perirenal depot growth in both sexes.

The overall trend in adipose tissue growth in subcutaneous, intermuscular and perirenal depot of both sexes indicates that adipocyte enlargement is the greater contributor to growth than the increase in adipocyte number. However, cellular enlargement does not consistently account for differences in adipose tissue growth between male and females. Differences between sexes are attributable mainly to differences in the change in adipocyte number rather than adipocyte size.

Previous studies involving males and females do not pursue the above concept. The study by Merkel *et al.* (1973) on Southdown and Suffolk ewes, wethers and rams showed that at 8 weeks ewes had bigger adipocytes in the subcutaneous depot than rams. As measurements were made on an age basis, a sex difference in amount of fat in the depot was not accounted for. Similarly, the study of Schön (1978) on the development of fat cells in different anatomical locations, in bulls and heifers, categorised animals into different age groups. The results presented are therefore inappropriate for a sex comparison, although inspection of the results indicates that heifers had bigger adipocytes than bulls at the common age group of 520 days. Evidence that a difference in the amount of fat in the depots between sexes contributes to differences in adipocyte size is shown in Table 20. At the same amount of depot fat, representing similar stages of fat maturity, males and females do not differ significantly in adipocyte volume. However, in a comparison at the same fat free carcass weight but at different fatness, females have bigger adipocytes than males for all three depots studied.

The trend whereby differences in adipose tissue growth are due to differences in the rate of increase in adipocyte number is also observed for a between depot comparison. In both sexes, the subcutaneous depot is the fastest growing, intermuscular is intermediate and perirenal is the slowest (Table 12a). A similar order is observed for the rate of increase in LIPT relative to LIPA (Table 18) and the extent of the increase in NA (Table 20), from birth to maturity. Adipocyte size changes do not reflect the order observed in the relative growth of the depots. For instance the rate of increase in LIPA (Table 19b) is fastest in perirenal and slowest in subcutaneous depot in both sexes. Furthermore, the extent of the increase in LIPA from birth to maturity in females is greatest in perirenal and smallest in the subcutaneous depot, while in males, subcutaneous showed the greatest increase and intermuscular the smallest. Hence differences in relative growth of the fat may be attributed to a difference in the rate of increase in number. A similar conclusion was reached by Broad *et al.* (1980) in an investigation of the growth of the subcutaneous, intermuscular and internal cavity depots in sheep, ranging from 120-day foetuses to 5-year old ewes. In Friesian and Hereford cattle, Truscott *et al.* (1980) observed that the perirenal depot grew solely by adipocyte enlargement whereas in the subcutaneous depot, adipocyte 'recruitment' was also involved.

3.4 BONE GROWTH

3.4.1 RESULTS

3.4.1.1 Relative growth of individual bones

The allometric equations relating the growth of individual bones to total side bone (TSB) weight in male and female Jersey cattle are given in Table 21. A trend is observed in which males have higher growth ratios (*b*) than females in the cranial vertebrae and ribs; significantly higher *b* values were observed for all the cervical vertebrae except the sixth, the first three thoracic vertebrae and the first five ribs. Females have significantly higher *b* values than males for the pelvic girdle and the sixth lumbar and second

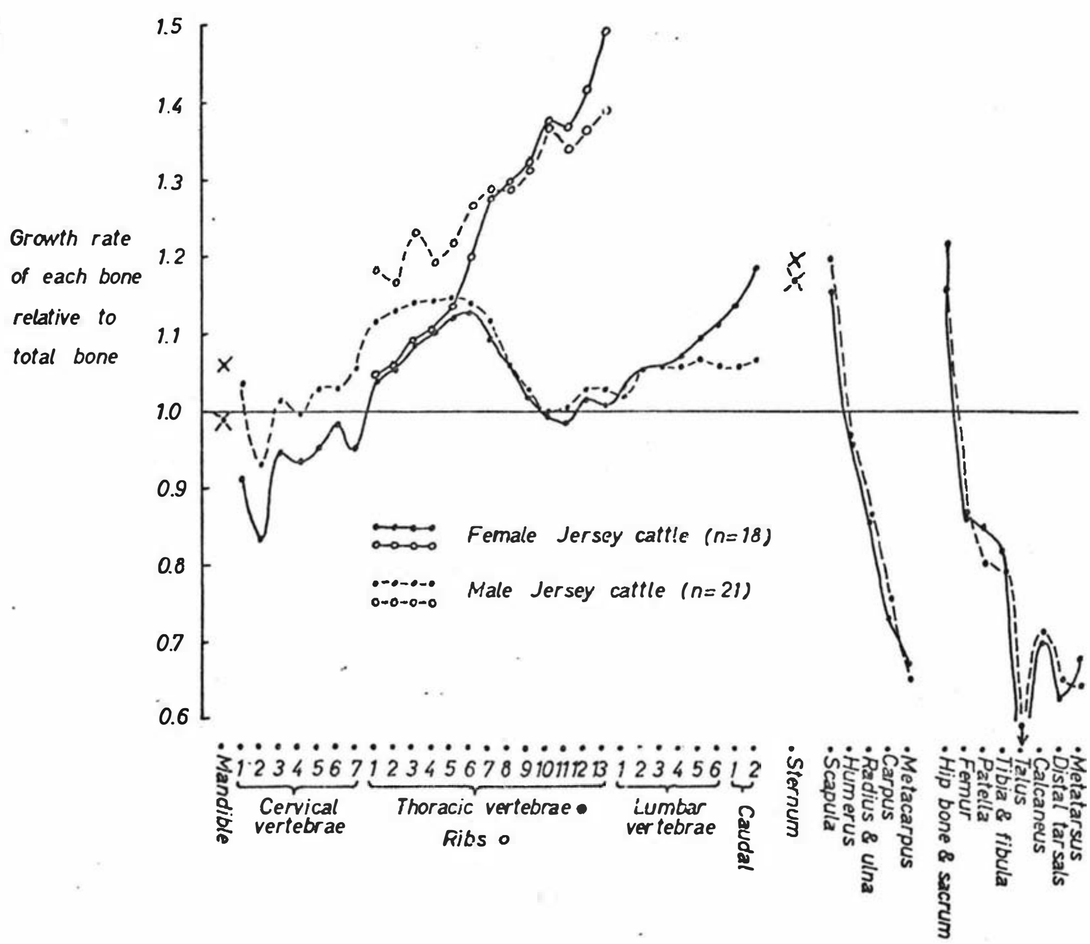


Figure 29: Growth ratios of individual bones showing the growth gradient pattern of bone in the carcass.

Table 21: Double logarithmic regressions comparing the growth of individual bone weights relative to total side bone weight, in grammes, between 21 male and 18 female Jersey cattle, from birth to maturity.

Individual bones		Male				Female		
		Growth Ratio $b\Phi$	s_b	Constant	Sex Diff.	Growth Ratio $b\Phi$	s_b	Constant
Cervical vertebrae:	1	1.037**	.012	-1.747	+++	0.912**	.023	-1.308
	2	0.931**	.020	-1.300	+++	0.835***	.017	-0.983
	3	1.022	.026	-1.792	+	0.945*	.024	-1.514
	4	1.001	.024	-1.687	+	0.934**	.022	-1.450
	5	1.026	.017	-1.768	++	0.947*	.021	-1.485
	6	1.033	.023	-1.770	NS	0.984	.022	-1.592
	7	1.057*	.020	-1.937	+++	0.948*	.021	-1.543
	Total	1.012	.018	-0.858	++	0.926***	.017	-0.555
Thoracic vertebrae:	1	1.119***	.021	-2.115	+	1.051**	.017	-1.875
	2	1.133***	.015	-2.222	++	1.068***	.012	-1.971
	3	1.143***	.013	-2.292	++	1.085***	.016	-2.064
	4	1.144***	.012	-2.324	NS	1.112***	.015	-2.187
	5	1.150***	.014	-2.364	NS	1.125***	.017	-2.254
	6	1.142***	.015	-2.371	NS	1.126***	.017	-2.293
	7	1.093***	.014	-2.232	NS	1.090***	.014	-2.210
	8	1.062**	.018	-2.154	NS	1.056**	.016	-2.121
	9	1.026	.015	-2.045	NS	1.019	.016	-2.016
	10	1.001	.016	-1.979	NS	0.992	.016	-1.943
	11	1.014	.017	-2.022	NS	0.978	.021	-1.893
	12	1.031	.022	-2.046	NS	1.016	.019	-1.994
	13	1.033	.018	-2.021	NS	1.013	.013	-1.945
	Total	1.094***	.013	-1.086	NS	1.063***	.012	-0.961
Lumbar vertebrae:	1	1.020	.025	-1.912	NS	1.026	.019	-1.932
	2	1.065***	.014	-2.035	NS	1.053**	.017	-1.979
	3	1.057**	.017	-1.969	NS	1.060**	.019	-1.979
	4	1.061**	.016	-1.974	NS	1.074***	.018	-2.019
	5	1.073***	.013	-2.014	NS	1.094***	.015	-2.087
	6	1.061***	.011	-1.974	+	1.108***	.015	-2.140
	Total	1.056***	.013	-1.203	NS	1.071***	.016	-1.251
Caudal vertebrae:	1	1.065*	.026	-2.717	NS	1.131*	.046	-2.925
	2	1.067*	.027	-2.774	+	1.185***	.044	-3.159
	Total	1.066*	.025	-2.444	NS	1.156**	.043	-2.733
Ribs:	1	1.184***	.022	-2.707	+++	1.046	.027	-2.208
	2	1.172***	.023	-2.819	+++	1.056*	.022	-2.376
	3	1.228***	.029	-2.988	++	1.099**	.025	-2.481
	4	1.190***	.021	-2.772	+	1.110***	.022	-2.470
	5	1.218***	.026	-2.809	+	1.143***	.025	-2.518
	6	1.272***	.034	-2.957	NS	1.214***	.026	-2.706
	7	1.292***	.031	-2.992	NS	1.282***	.018	-2.914
	8	1.288***	.034	-2.982	NS	1.304***	.030	-3.005
	9	1.318***	.033	-3.141	NS	1.332***	.027	-3.146
	10	1.367***	.037	-3.403	NS	1.377***	.034	-3.387
	11	1.337***	.035	-3.377	NS	1.367***	.041	-3.436
	12	1.367***	.040	-3.570	NS	1.416***	.059	-3.670
	13	1.195	.135	-3.081	NS	1.491***	.067	-4.088
	Total	1.272***	.025	-1.947	NS	1.251***	.023	-1.832

Table 21 (continued)

Individual bones	Male			Sex Diff	Female		
	Growth Ratio $b\Phi$	s_b	Constant		Growth Ratio $b\Phi$	s_b	Constant
Mandible	0.989	.036	-1.042	NS	1.071*	.033	-1.272
Sternum	1.165***	.032	-1.628	NS	1.204***	.024	-1.722
Scapula	1.203***	.014	-2.130	NS	1.162***	.017	-1.959
Humerus	0.963*	.013	-0.944	NS	0.966*	.014	-0.974
Radius and ulna	0.878***	.011	-0.738	NS	0.875***	.013	-0.746
Carpus	0.756***	.023	-0.958	NS	0.732***	.028	-0.911
Metacarpus	0.647***	.015	-0.173	NS	0.674***	.020	-0.315
Os coxae and sacrum	1.158***	.013	-1.315	+++	1.224***	.013	-1.527
Femur	0.867***	.018	-0.455	NS	0.874***	.015	-0.491
Patella	0.797***	.027	-1.407	NS	0.858***	.022	-1.665
Tibia and fibula	0.790***	.016	-0.342	NS	0.817***	.014	-0.454
Talus	0.444***	.035	0.201	NS	0.462***	.029	0.078
Tuber calcis	0.705***	.021	-0.706	NS	0.699***	.021	0.728
Distal tarsus	0.651***	.033	-0.714	NS	0.631***	.026	-0.688
Metatarsus	0.635***	.018	-0.096	NS	0.680***	.022	-0.281

Φ Regression coefficient b, standard error s_b.

* Values of b bearing this superscript are significantly ($P < 0.05$) different from 1.

\+ Significantly ($P < 0.05$) different in b between sexes.

caudal vertebrae. Males and females vary their growth ratios in the same pattern generally, with undulating b values for vertebrae, a craniocaudal increase within the ribs,and a proximodistal decrease within the limb bones, as illustrated in Fig. 29.

The weights of bones showing a significant sex difference in b values are predicted at three TSB weights of 8.7, 15.0 and 26.0 kg (Table 22). The overall total weight of these bones is approximately 27% TSB weight. At the same TSB weight, the differences between sexes in the overall weights of these bones are small (e.g. 35, 48 and 70 g respectively, at the three TSB weights) with females having heavier weights.

The TSB weights of a half mature and mature male and female in Table 22, are based on Table 2 (Section 3.1). At the same maturity, these bones make a lighter contribution in females than in males. Expressesd as a percentage of TSB and as a percentage of half carcass weight (HCWT), differences between sexes in these bones are

Table 22: Weights of bones in grammes for male and female Jersey cattle, at various total side bone (TSB) weight, as calculated from the regressions given in Table 21.

(a) Bones whose *b* values are significantly higher in males than females.

			Half mature		Mature		
		Male	Female	Male	Female	Male	Female
TSB		8720	8720	15000	15000	26000	26000
Half cervical vertebrae:	1	109	97	192	159	339	262
	2	117	102	194	160	323	253
	3	86	81	150	136	263	228
	4	91	85	156	141	270	236
	5	94	88	165	148	289	249
	7	85	78	150	131	269	220
Half thoracic vertebrae:	1	99	93	181	164	335	291
	2	88	87	162	154	302	278
	3	82	82	152	147	284	266
Ribs:	1	91	82	173	145	331	257
	2	63	61	119	108	227	193
	3	71	71	138	128	271	235
	4	83	80	158	146	303	270
	5	98	97	189	180	370	338
Total bone weight		1257	1184	2279	2047	4176	3576

(b) Bones whose *b* values are significantly lower in males than females.

			Half mature		Mature		
		Male	Female	Male	Female	Male	Female
TSB		8720	8720	15000	15000	26000	26000
Half lumbar vertebra:	6	81	84	143	154	257	283
Half caudal vertebra:	2	14	16	24	31	44	59
Os coxae and half sacrum		886	989	1659	1921	3138	3767
Total bone weight		981	1089	1826	2106	3439	4109
Overall total (a) + (b)		2238	2273	4105	4153	7615	7685
% TSB		25.7	26.1	27.4	27.7	29.3	29.6
† HCWT (kg)		42.0	44.9	84.3	90.9	171	186
% HCWT		2.3	2.4	2.2	2.3	2.0	2.2

† Half carcass weight (HCWT) as estimated from the regression in Table 1, section 3.1.

small, regardless of whether comparisons are made at the same TSB or maturity.

3.4.1.2 Change in linear measurements

Table 23 gives the allometric equations of various linear measurements made on live animals. When empty body weight (EBWT) was used as the x variable, sexes do not differ significantly in their b values for each of the measurements. However, when TSMB was used as the x variable, significant differences in b values between males and females were observed for the measurements in crown-rump, height at withers and width between the tuber ischii. Hence, females are longer, taller and wider at the hip than males, at the same fat free carcass weight.

The allometric equations relating linear measurements of individual bones to their respective bone weights are shown in Table 24. In all measurements, except for scapular and humeral length, females have higher *b* values than males, and significantly so for the *b* values of humeral width, metacarpal length, and the conjugate and vertical diameters of the pelvis.

During growth there are differences between sexes in the change in shape of the pelvis. In females, the *b* values of all five measurements of the pelvis were significantly greater than 0.333, suggesting that the pelvis is changing its shape. In males, the *b* values of the conjugate and vertical diameters do not differ significantly from 0.333, and are significantly different from the corresponding female values. In females, the order of the *b* values of internal pelvic dimensions, from highest to lowest, was vertical, transverse and conjugate; in males, it was transverse, conjugate and vertical. Hence,

Table 23: Double logarithmic regressions relating the change in linear measurements, in millimeters, to empty body weight (EBWT) and total side muscle plus bone (TSMB) weight, in grammes, in male and female Jersey cattle, from birth to maturity.

		Male				Female		
x	Linear measurements	Growth Ratio *b*Φ	s_b	Constant	Sex Diff.	Growth Ratio *b*Φ	s_b	Constant
EBWT	Crown - rump	.319	.011	1.463	NS	.334	.014	1.388
	Minimum neck circumference	.330	.014	1.138	NS	.293*	.019	1.283
	Height at withers	.223***	.010	1.863	NS	.242***	.013	1.773
	Width between tuber coxae	.431***	.025	0.331	NS	.393*	.026	0.547
	Width between tuber ischii	.455***	.031	-0.424	NS	.544***	.039	-0.699
TSMB	Crown - rump	.312	.014	1.685	+	.369	.017	1.463
	Minimum neck circumference	.327	.012	1.351	NS	.322 •	.023	1.353
	Height at withers	.219***	.011	2.016	+	.266***	.016	1.830
	Width between tuber coxae	.423**	.026	0.625	NS	.427*	.035	0.659
	Width between tuber ischii	.449**	.031	-0.123	++	.598***	.037	-0.618

Φ Regression coefficient *b*, standard error s_b.

* Values of *b* bearing this superscript are significantly ($P < 0.05$) different from 0.333 and therefore indicate disproportionality.

\+ Significantly ($P < 0.05$) different in *b* between sexes.

Table 24: Double logarithmic regressions relating various linear measurements of individual bones, in millimeters, to the respective bone weight, in grammes, for 21 male and 18 female Jersey cattle, from birth to maturity.

		Male				Female		
x	*y*	Growth Ratio *b*Φ	s_b	Constant	Sex Diff	Growth Ratio *b*Φ	s_b	Constant
Mandible	Length	.309	.015	1.566	NS	.312	.006	1.561
	Height	.376	.018	1.138	NS	.400***	.011	1.084
Scapula	Length	.339	.007	1.629	NS	.336	.008	1.652
	Width	.384	.031	0.592	NS	.407**	.019	0.558
Humerus	Length	.312	.010	1.498	NS	.312	.012	1.511
	Width	.320	.023	0.564	++	.411**	.020	0.308
Radius and ulna	Ulnar length	.325	.010	1.583	NS	.347	.007	1.547
	Radial length	.291*	.010	1.568	NS	.310	.010	1.538
	Radial width	.363	.015	0.295	NS	.414**	.024	0.163
Metacarpus	Length	.192***	.010	1.795	+	.231***	.013	1.729
	Width	.386**	.017	0.408	NS	.394***	.015	0.368
Rib 1	Length	.348	.008	1.653	NS	.387	.044	1.5[illegible]
Rib 2	Length	.325	.011	1.834	NS	.341	.014	1.830
Os coxae and sacrum	Tuber ischii	.498***	.028	0.263	NS	.549***	.033	0.266
	Tuber coxae	.453***	.011	0.994	NS	.475***	.013	0.967
	Conjugate	.340	.018	1.028	+	.399***	.013	0.903
	Transverse	.400***	.013	0.729	NS	.434***	.016	0.677
	Vertical	.336	.014	0.917	+++	.450***	.028	0.644
Femur	Length	.370**	.010	1.389	NS	.382***	.010	1.377
	Width	.388**	.017	0.313	NS	.425***	.021	0.210
Tibia (and fibula)	Length	.330	.011	1.548	NS	.353	.011	1.505
	Width	.350	.014	0.405	NS	.386	.040	0.294
Metatarsus	Length	.210***	.010	1.795	NS	.239***	.014	1.750
	Width	.410***	.015	0.374	NS	.445***	.015	0.278

Φ Regression coefficient *b*, standard error s_b.

* Values of *b* bearing this superscript are significantly ($P < 0.005$) different from 0.333 and therefore indicate disproportionality.

\+ Significantly ($P < 0.05$) different in *b* between sexes.

Table 25: Predictions of linear measurements of the pelvic girdle, in millimetres, and their ratios at various weight of os coxae and sacrum, in grammes, using the equations in Table 24.

	Male	Female	Male	Female	Male	Female
Weight of os coxae and sacrum	275	275	4000	4000	6310	6310
Tuber ischii	30	40	114	175	143	225
Tuber coxae	126	134	422	476	519	592
Conjugate	72	75	179	219	209	263
Transverse	51	54	148	174	177	212
Vertical	55	55	134	184	156	226
Tuber ischii:Tuber coxae	0.24	0.30	0.27	0.37	0.28	0.38
Vertical:Conjugate	0.76	0.73	0.75	0.84	0.75	0.86
Vertical:Transverse	1.08	1.02	0.91	1.06	0.88	1.07
Conjugate:Transverse	1.41	1.39	1.21	1.26	1.18	1.24

it can be expected that there are differences in the shape of the pelvis between sexes during growth, especially for the vertical measurement.

Predictions of the pelvic dimensions at various weights of os coxae plus sacrum, ranging from birth to maturity, are given in Table 25. There is a greater increase in each of the measurements, from birth to maturity, in females than in males. The ratio of the widths between tuber ischii and tuber coxae indicate that females have a wider pelvis externally.

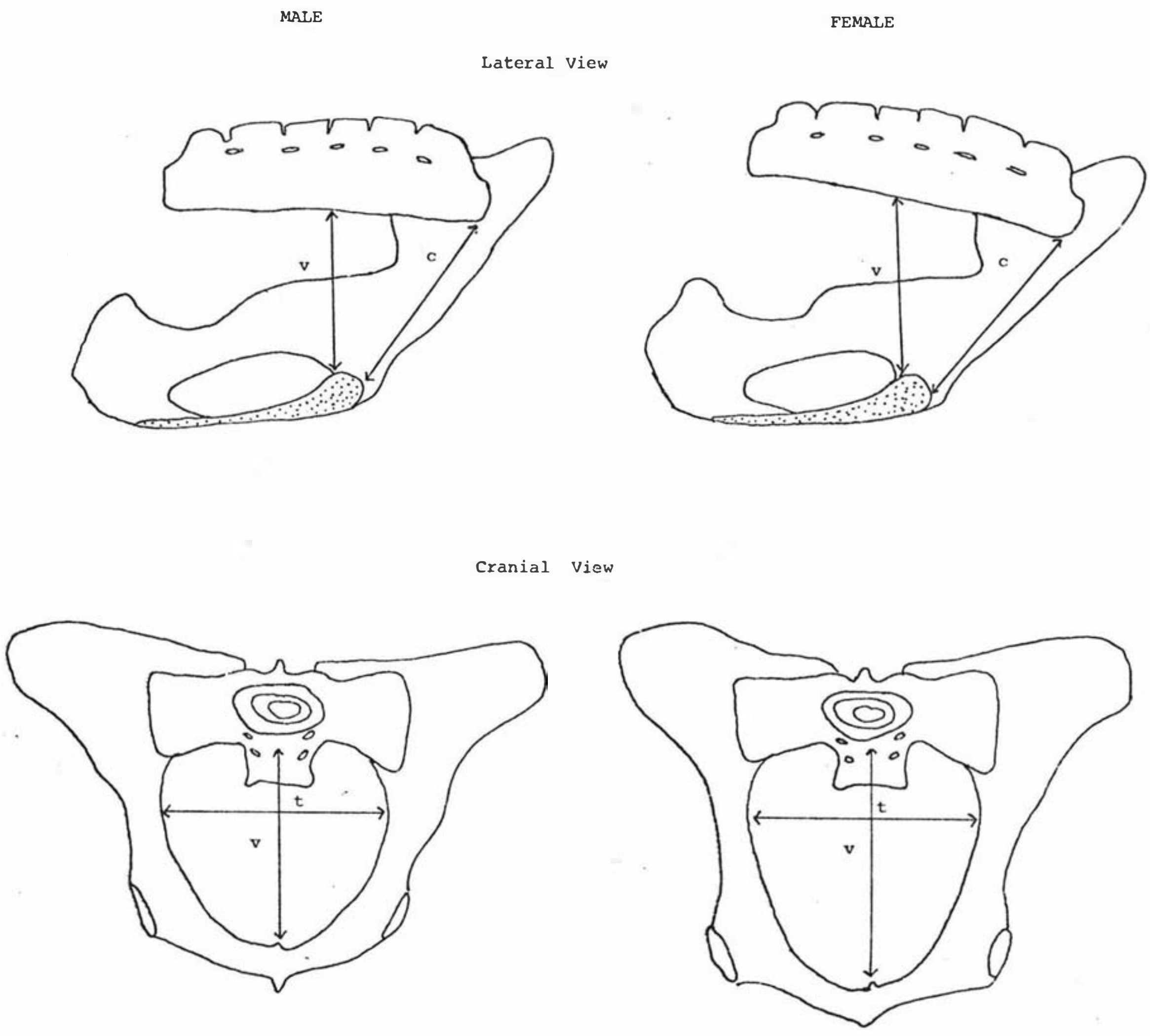


Figure 30: Differences in shape of pelvic cavity between male and female Jersey cattle, at maturity. v = vertical diameter; c = conjugate diameter; and t = transverse diameter.

The internal change in shape of the pelvic cavity is described by the vertical, transverse and conjugate diameters and their ratios. As the animal grows, the ratio of vertical:conjugate increases in females (0.73 t0 0.86) but not in males (0.75 to 0.74). In females, the faster increase in vertical than in conjugate diameter (Table 24) shows that the caudal end of the sacrum becomes raised relative to the hip bones and therefore the pelvic inlet becomes directed cranioventrally during growth (Fig. 30). In males, this angulation of the sacroiliac joint remains relatively constant as suggested by the vertical:conjugate ratio (Table 25) and the growth ratios of the two measurements (Table 24).

In females, the vertical:transverse ratio increases and is more than 1 at all stages of growth, while in males this ratio decreases to 0.88. Therefore, in females, the pelvic cavity expands more vertically than transversely, while in males, the converse is true (Fig. 30).

The conjugate:transverse ratio is greater than 1 and decrease from birth to maturity in both sexes. This is because the transverse diameter is faster growing than the conjugate diameter (Table 24).

Thus two processes occur simultaneously to produce sexual dimorphism of the bovine pelvis; the sacroiliac joint changes its angle and the shape of the pelvic inlet changes.

3.4.2 DISCUSSION

3.4.2.1 Growth patterns and distribution of bones

The present study indicates that in both sexes, there is a proximo-distal gradient of decreasing growth in the limbs (Table 21 & Fig. 29). This agrees with the general pattern of growth described in cattle (Seebeck and Tulloh, 1968b; Seebeck, 1973b; Robelin, 1978; Jones, Price and Berg, 1978; Berg, Anderson and Liboriussen, 1978d), sheep (Hammond, 1932) and pigs (McMeekan, 1940; Davies, 1979). Cranio-caudally, there is a fluctuating growth gradient within the vertebrae of both sexes (Fig. 29); this pattern has not been reported in cattle or sheep but has been noted in barrows (Davies, 1979). Not previously described for any species is the craniocaudally increasing growth gradient observed in the ribs of both sexes. The general similarity in growth gradient patterns between male and female Jersey cattle implies a functional similarity for each bone between sexes, but because of variation in cervical, cranial thoracic and pelvic regions (Fig. 29), some bones must differ in their ability to perform their respective function between sexes.

At the same TSB weight, sex differences in bone weight distribution are small (Table 22) and commercially unimportant. This agrees with the conclusion of Jones *et al.* (1978) based on three cattle breeds and three sexes. Although Robelin (1978) found that in the Charolais x Salers and Limousin cattle breeds, males have significantly more bone than females at the same empty body weight (EBWT); differences between sexes were only 1.0% and 0.8% of EBWT, respectively, for the two breeds. These comparisons were made at the same EBWT; the sex differences may therefore be due to differences in fatness and maturity. In Table 22, predictions of bones whose *b* values are significantly different between sexes, indicate that at the same maturity, females have less bone than males. When expressed as percentages of TSB and HCWT differences between sexes are small.

Examination of the growth ratios of individual vertebrae and ribs (Table 21 & Fig. 28) suggests a faster developing forequarter in males than in females. The weight of each of these bones is only a small part of TSB. Therefore, a significant difference in *b* values indicates a real effect in this region, rather than reflecting differences elsewhere in the skeleton. The *b* value for the total cervical vertebrae is significantly higher in males than females. This differs from the conclusions of Jones *et al.* (1978), that sex regressions for these bones were homogenous relative to TSB. Tables 21 & 22 indicate that males have a faster growing rib cage and heavier ribs, especially for the first five ribs, than those in females. This differs from that reported by Jones *et al.* (1978), where bulls have lighter ribs than heifers, at the same TSB weight.

The general similarities between sexes in bone distribution indicate that bones are functionally similar in males and females. Davies

(1979) observed that "growth centres" in the musculoskeletal system of the pig are located at the pivots of the forelimb and hindlimb pendulums. In the pig, the hindlimb pivot appears to be progressively more important for propulsion than the forelimb pivot, as the animal grows. In cattle, the forelimb peak, which occurs within the first eight thoracic vertebrae, and the hindlimb peak, which occurs within the last five lumbar and first two caudal vertebrae, have growth ratios significantly greater than 1 (Table 21 & Fig. 29). This suggests that the two limbs have similar importance for propulsion. The forelimb may be more important for propulsion in males than in females.

3.4.2.2 Growth patterns for pelvic dimensions and other measurements

Linear body measurements have been used to describe growth in cattle (Brody, 1945; Wilson, 1973; Russel, 1975), and metacarpal and metatarsal measurements have been used as indices of growth and carcass characteristics in steers and heifers (Wilson *et al.* 1977). In the present study, the purpose of linear measurements is to examine the shape of males and females. Table 23 indicates that females grow longer and taller, and have wider hips than males. At the same TSMB, this would mean that male carcasses will be blockier in terms of muscle presentation, than female carcasses. As noted by Colomer-Rocher, Bass and Johnson (1980) this shape is advantageous in terms of consumer preference for a "thick and plump" steak.

Table 24 shows that there are only small differences in the length, width and height of bones in males and females. It is in the pelvic dimensions that phenotypic differences between sexes are most apparent (Table 25). External pelvic measurements indicate that females have broader hips than males. The internal pelvic measurements show that postnatally, the pelvic girdle in females changes its shape to facilitate parturition; the pelvic inlet becomes more ventrally directed towards the abdominal floor, probably through movement about the sacroiliac joint; the vertical, conjugate and transverse diameters have b values significantly greater than 0.33; and the vertical diameter is the fastest changing dimension. Although pelvic dimensions in female cattle have been studied in relation to dystocia (Bellows *et al.*, 1971 a & b; Laster, 1974; Neville *et al.*, 1978), none have examined these dimensions in males. These studies were also concerned with pelvic area (height x width of pelvic opening) rather than pelvic shape, which is an additional critical factor in dystocia. The present results on males indicate that the pelvis does not alter its sacroiliac angulation, and the vertical and conjugate diameters do not show disproportionality; the vertical diameter has the lowest *b* values. Hence, a problem of dystocia may arise when female adaptive changes, especially in the vertical plane, do not occur postnatally.

4.0 GENERAL CONCLUSIONS

Muscle fibre number is the critical trait in determining sex differences in muscle growth. The rate of increase in the number of adipocytes accounts for differences in the rate of fat deposited between sexes. Because sex differences in growth are genetically based, the evidence from this particular model suggests that differences in cell number and in the ability to increase cell number arise as a result of genetic differences.

Postnatally, growth of muscle and fat is largely by increasing cell size because the number of muscle fibres remains constant and the increase in number of adipocytes is small compared to the increase in size of adipocytes. Presumably, therefore, non-genetic growth modifications will involve cell size; it should be easier to alter cell size than to alter cell number, postnatally.

Genetic and non-genetic factors, operating from conception to birth, will determine the number of muscle fibres in individual muscles and the adipocyte characteristics of each depot. These traits determine the ceiling to which these tissues can grow. Postnatally, environmental factors such as nutrition, exercise and hormones modify the level of expression. In this experimental model, males and females superficially do not appear sexually dimorphic in the neck at birth but become dimorphosed postnatally; the potential to grow is present at birth but is not expressed by a difference in tissue quantity. This pattern of growth is favourable to the survival of a calf because a large foetus is a cause of dystocia. Hence, antenatally, the establishment of the potentials of tissues to grow should be the prime concern while postnatally, it should be to provide the necessary conditions for the expression of these potentials.

APPENDIX 1: JERSEY CATTLE CARCASS DISSECTION WORKSHEET

I.D. No..........

Department of Anatomy & Physiology, Faculty of Veterinary Science
Massey University

A. SLAUGHTER DATA

Sex	Date of slaughter	....
Age	Liveweight at slaughter	....
Skin including tail		....
Left forelimb		....
Left hindlimb		....
Left thoracic wall		....
Left abdominal wall		....
Udder		....
Udder fat/Cod fat		....
Testes: right .... left .... total		....
Penis		....
Preputial mm.		....
M. retractor penis		....
M. cremaster		....
M. ischiocavernosus		....
M. bulbospongiosus		....
M. urethralis		....
1. Diaphragm: muscular part		....
tendinous part		....
Cavity fat		....
Thoracic viscera		....
Abdominal and pelvic viscera		....
Miscellaneous (scrap etc)		....
Forequarter: at slaughter		....
at dissection	(date ....)	....
Hindquarter: at slaughter		....
at dissection	(date ....)	....

TOTAL WEIGHT AT SLAUGHTER ....

PERCENTAGE LOSS FROM LIVEWEIGHT ....

2 I.D. No. ....

B. NON-CARCASS COMPONENTS

Thoracic viscera

Heart	....
Lungs	....
Scrap	....
TOTAL THORACIC VISCERA	....

Abdominal and pelvic viscera

Liver				....
Spleen				....
Left kidney				....
Right kidney				....
Digestive tract:	full	empty	contents	
Stomachs	....	....	....	
Intestine	....	....	....	
Total	....	....	....	....
Perirenal fat				....
Pelvic fat				....
Uterus				....
Left ovary				....
Right ovary				....
Scrap				....

TOTAL ABDOMINAL AND PELVIC VISCERA ....

3 I.D. No................

C. FOREQUARTER SPINAL MUSCLES

1	Sternomandibularis	....
2	Sternomastoideus	....
3	Sternothyrohyoideus	....
4	Omohyoideus	....
5	Splenius capitis et cervicis	....
6	Iliocostalis thoracis	....
7	Longissimus thoracis	....
8	Longissimus cervicis	....
9	Longissimus capitis	....
10	Longissimus atlantis	....
11	Semisponalis capitis, cervicis et thoracis	....
12	Spinalis cervicis et thoracic	....
13	Scalenus dorsalis	....
14	Scalenus ventralis	....
15	Intertransversarii cervicis (dorsal and ventral)	....
16	Intertransversarius longus	....
17	Longus capitis	....
18	Longus colli	....
19	Obliquus capitis caudalis	....
20	Obliquus capitis cranialis	....
21	Rectus capitis dorsalis major	....
22	Rectus capitis dorsalis minor	....
23	Rectus capitis ventralis	....
24	Rectus capitus lateralis	....
25	Multifidis cervicis	....
26	Multifidis thoracis	....
27	Interspinales	....
28	Scrap muscle	....

TOTAL FOREQUARTER SPINAL MUSCLES ....

4 I.D. No...............

D. FOREQUARTER ABDOMINAL AND THORACIC MUSCLES

1	Cutaneus trunci (part)	....
2	Rectus abdominis (part)	....
3	Obliquus externus abdominis (part)	....
4	Transversus abdominis (part)	....
5	Rectus thoracis	....
6	Serratus dorsalis cranialis	....
7	Serratus dorsalis caudalis (part)	....
8	Intercostales (part)	....
9	Transversus thoracis	....
10	Scrap muscles	....

TOTAL ABDOMINAL AND THORACIC MUSCLES ....

E. FOREQUARTER EXTRINSIC MUSCLES

1	Trapezius	....
2	Brachiocephalicus	....
3	Omotransversarius	....
4	Rhomboideus	....
5	Latissimus dorsi	....
6	Serratus ventralis cervicis et thoracis	....
7	Pectoralis profundus	....
8	Pectoralis superficialis	....

TOTAL FOREQUARTER EXTRINSIC MUSCLES ....

TOTAL ABDOMINAL, THORACIC AND EXTRINSIC MUSCLES ....

5 I.D. No...............

F. FORELIMB MUSCLES

1	Deltoideus	....
2	Infraspinatus	....
3	Supraspinatus	....
4	Coracobrachialis	....
5	Subscapularis	....
6	Teres major	....
7	Biceps brachii	....
8	Teres minor	....
9	Tensor fasciae antebrachii	....
10	Triceps brachii: lateral head	....
11	Triceps brachii: long head	....
12	Triceps brachii: medial head	....
13	Brachialis	....
14	Anconeus	....
15	Scrap muscles	....
	TOTAL PROXIMAL THORACIC LIMB MUSCLES	....
16	Extensor carpi radialis	....
17	Extensor digitorum lateralis	....
18	Extensor digitorum communis (3 heads)	....
19	Abductor pollicis longus	....
20	Ulnaris lateralis	....
21	Flexor carpi ulnaris	....
22	Flexor carpi radialis	....
23	Flexor digitorum superficialis	....
24	Flexor digitorum profundus: ulnar head	....
25	radial head	....
26	humeral head	....
27	Scrap muscles	....
	TOTAL DISTAL THORACIC LIMB MUSCLES	....
	TOTAL FORELIMB MUSCLES (PROXIMAL + DISTAL)	....

I.D. No..........

G FOREQUARTER BONES

Cervical vertebrae	....	x ½ =	....
Thoracic vertebrae (part)	....	x ½ =	....
Costal cartilage & sternum	....	x ½ =	....
SUB TOTAL	....		....
Ribs (part)	....		
Scapula	....		
Humerus	....		
Radius and ulna	....		
Carpal bones	....		
Metacarpus	....		
TOTAL FOREQUARTER BONES	....		....

WEIGHTS OF INDIVIDUAL VERTEBRAE AND RIBS

C1	....	T1	....	Rib 1	....
C2	....	T2	....	Rib 2	....
C3	....	T3	....	Rib 3	....
C4	....	T4	....	Rib 4	....
C5	....	T5	....	Rib 5	....
C6	....	T6	....	Rib 6	....
C7	....	T7	....	Rib 7	....
C8	....	T8	....	Rib 8	....
Total	....	T9	....	Rib 9	....
		T10	....	Rib 10	....
		T11	....	Rib 11	....
	(part)	T12	....	Rib 12	....
		Total	....	Total	....

Spinal cord (part) .... Spinal fat (part) ....

LINEAR MEASUREMENTS	LENGTH	WIDTH
Cervical vertebrae	....	
Thoracic vertebrae (part)	....	
1st rib	....	
8th rib	....	
Scapula	....	....
Humerus	....	....
Ulna	....	....
Radius	....	....
Metacarpus	....	....

Mandible: Height .... Length ....

H. FOREQUARTER FAT | I.D. No.............

Subcutaneous fat	....
Intermuscular fat	....
Cavity fat	....
Sternal fat	....
Fat remaining on bone	....
TOTAL FOREQUARTER FAT	....
Fat thickness at the 12th rib	....
I. FOREQUARTER MISCELLANEOUS	....
Forequarter scrap:	
Fasciae	....
Tendons, ligaments	....
Ligamentum nuchae	....
RHS scrap	....
LHS scrap	....
M. interosseus	....
Head	....
Trachea, oesophagus, etc.	....
Thymus	....
Hoof and skin	....
TOTAL FOREQUARTER MISCELLANEOUS	....
J. FOREQUARTER TOTALS	
Total muscle (C + D + E + F)	....
Total bone	....
Total fat	....
Total miscellaneous	....
TOTAL FOREQUARTER	....
Forequarter at slaughter (A)	....
Percentage dissection loss	....
K. HEAD (not included in the forequarter totals)	
1 Masseter	....
2 Digastricus	....
3 Temporalis	....
4 Pterygoideus medialis	....
5 Pterygoideus lateralis	....
6 Other muscles: buccinator	....
zygomaticus	....
depressor labiimaxillaris	....
caninus	....
levator labii maxillaris	....
Mandible	....

8

I.D. No.............

L. HINDQUARTER SPINAL MUSCLES

1	Longissimus lumborum		....
2	Iliocostalis lumborum		....
3	Multifidus lumborum		....
4	Coccygeus		....
5	Levator ani		....
6	Sacrocaudalis ventralis		....
7	Sacrocaudalsi dorsalis		....
8	Sublumbar muscles:	Psoas minor	....
9		Iliopscas	....
10		Quadratus lumborum	....
11	Scrap muscle		....

TOTAL HINDQUARTER SPINAL MUSCLES

M. HINDQUARTER ABDOMINAL AND THORACIC MUSCLES

1	Cutaneus trunci (part)	....
2	Rectus abdominis (part)	....
3	Obliquus internus abdominis	....
4	Obliquus externus abdominis (part)	....
5	Transversus abdominis (part)	....
6	Intercostals (part)	....
7	Retractor costae	....
8	Serratus dorsalis caudalis (part)	....
9	Scrap muscle	....

TOTAL HINDQUARTER ABDOMINAL AND THORACIC MUSCLES ....

9 I.D. No..............

N. HINDLIMB MUSCLES

1	Tensor fasciae latae	....
2	Biceps femoris	....
3	Semitendinosus	....
4	Gluteus medius	....
5	Gluteus accessorius	....
6	Gluteus profundus	....
7	Gemelli	....
8	Sartorius	....
9	Gracilis	....
10	Pectineus	....
11	Semimembranosus	....
12	Quadratus femoris	....
13	Adductor	....
14	Rectus femoris	....
15	Vastus lateralis	....
16	Vastus intermedius	....
17	Vastus medialis	....
18	Obturatorius externus (et internus)	....
19	Scrap muscle	....
	TOTAL PROXIMAL PELVIC LIMB MUSCLES	....
20	Gastrocmemius	....
21	Flexor digitorum superficialis	....
22	Peroneus tertius et extensor digitorum longus	....
23	Tibialis cranialis	....
24	Peroneus longus	....
25	Extensor digitorum lateralis	....
26	Popliteus	....
27	Flexor digitorum profundus	....
28	Scrap muscle	....
	TOTAL DISTAL PELVIC LIMB MUSCLES	....
	TOTAL HINDLIMB MUSCLES (PROXIMAL + DISTAL)	....

O. HINDLIMB BONES

Thoracic vertebrae (part)	....	x ½ =	....
Lumbar vertebrae	....	x ½ =	....
Os coxae and sacrum	....	x ½ =	....
Caudal vertebrae (1 to 2)	....	x ½ =	....
SUB TOTAL	....	x ½ =	....
13th rib	....		
Femur	....		
Patella	....		
Tibia	....		
Talus	....		
Calcaneus	....		
Distal tarsal bones	....		
Metatarsus	....		
TOTAL HINDQUARTER BONE	....		

WEIGHTS OF INDIVIDUAL VERTEBRAE:

T12 (part)	L1	Ca1 ....
T13	L2	Ca2 ....
Total	L3	Total...........
	L4	
	L5	
	L6	
	Total	

Spinal cord (part) .... Spinal fat ....

LINEAR MEASUREMENTS	LENGTH	WIDTH
Thoracic vertebrae (part)	....	
Lumbar vertebrae	....	
Sacrum	....	
Caudal vertebrae (1 to 2)	....	
Os coxae: (a) Between tuber ischii		....
(b) Between tuber coxae		....
Cranial pelvic aperture: (a) Conjugate diameter		....
(b) Transverse diameter		....
(c) Vertical diameter		....
Femur	....	....
Tibia	....	....
Metatarsus	....	....

P. HINDQUARTER FAT I.D. No...............

Subcutaneous fat	....		
Intermuscular fat	....		
Left and right perirenal fat	....	x ½ =	....
Left and right channel fat	....	x ½ =	....
Fat remaining on bone	....		....
TOTAL HINDQUARTER FAT	....		....

Q. HINDQUARTER MISCELLANEOUS

Hindquarter scrap:	
Fasciae	....
Tendons, ligaments	....
RHS scrap	....
LHS Scrap	....
M. extensor digitorum brevis	....
M. interosseus	....
Hoof and skin	....
TOTAL HINDQUARTER MISCELLANEOUS	....

R. HINDQUARTER TOTALS

Total muscle (L + M + N)	....
Total bone (O)	....
Total fat (P)	....
Total miscellaneous (Q)	....
TOTAL HINDQUARTER	....
Hindquarter at slaughter (A)	....
Percentage dissection loss	....

S. HALF CARCASS COMPONENTS

Total muscle (A1 + C + E + F + L + M + N)	....
Total bone (G-½ vertebrae + O - ½ vertebrae - ½ os coxae)	....
Total fat (H + P - ½ perirenal - ½ channel)	....
Total miscellaneous (I + Q; only F Q + H Q scrap)	....
TOTAL HALF CARCASS	....

APPENDIX 2: DISSECTION WORKSHEET FOR FOREQUARTER FAT

I.D. No................

SUBCUTANEOUS FAT	FASCIA	FAT
1 Trapezius	....	....
2 Thoracic limb	....	....
3 Latissimus dorsi	....	....
4 Cutaneus trunci-abdominal	....	....
5 Pectoral	....	....
6 Neck	....	....
TOTAL FOREQUARTER SUBCUTANEOUS FASCIA & FAT	....	....

INTERMUSCULAR FAT		
1 Axial muscles	....	....
2 Extrinsic muscles	....	....
3 Thoracic rib cage (intercostals)	....	....
4 Abdominal muscles	....	....
5 Proximal thoracic limb	....	....
6 Distal thoracic limb	....	....
TOTAL FOREQUARTER INTERMUSCULAR FASCIA & FAT	....	....

FAT REMAINING ON BONE	
1 Cervical and thoracic vertebrae	....
2 Sternum and rib	....
3 Forequarter long bones	....
TOTAL FOREQUARTER FAT ON BONE	....

APPENDIX 3: DISSECTION WORKSHEET FOR HINDQUARTER FAT

I.D. No...............

SUBCUTANEOUS FAT	FASCIA	FAT
I. Cutaneous trunci-tensor fasciae latae	....	....
II. Medial pelvic limb	....	....
III. Lateral pelvic limb	....	....
IV. Abdominal	....	....
V. Longissimus	....	....
IV. Perianal	....	....

INTERMUSCULAR FAT		
1 Axial muscles	....	....
2 Sublumbar muscles	....	....
3 Intercostal muscles (part)	....	....
4 Abdominal muscles	....	....
5 Proximal pelvic limb	....	....
6 Distal pelvic limb	....	....
TOTAL HINDQUARTER INTERMUSCULAR FASCIA & FAT	....	....

FAT REMAINING ON BONE	
1 Vertebrae	....
2 Pelvic girdle and sacrum	....
3 Hindquarter long bones	....
TOTAL HINDQUARTER FAT ON BONE	
Right perirenal fat	....
Left perirenal fat	....
TOTAL PERIRENAL FAT	....
Left and right channel fat	....

APPENDIX 4: MALE JERSEY CATTLE CARCASS DISSECTION DATA (g)

* Age in days or number of incisor teeth in parentheses

Identification Number	23	24	25	40	41	26	27	28	29	32	33	37	39	36	21	35	34	22	38	30	31
Age*	1	1	1	1	5	30	30	35	67	100	136	(2)	(2)	(2)	540	(2)	(2)	(4)	(5)	2520	1800
Liveweight at slaughter	24100	20000	28200	22000	29000	46400	50900	46400	61700	75500	74500	109000	122000	172000	173000	177000	223000	291000	314060	614000	673000
Empty body weight	23700	19600	27700	21000	28000	43700	49300	44800	55400	65700	63900	97300	116000	150000	152000	153000	193000	259000	279000	585000	610000
Half carcass weight	6108	5093	7544	6399	8094	13799	14620	14278	16342	17187	16423	22690	34128	44839	47514	45161	51262	76289	80517	199822	186695
Total side muscle + bone	5395	4563	6623	5597	7193	12225	12888	12814	13811	15041	14598	19418	27501	39093	41532	39312	44146	65776	69342	166561	145352
Total side muscle	3383	2862	4397	3734	4878	8540	9244	9163	9735	10475	10203	13432	20734	29859	31547	29099	33661	51642	54221	142140	116087
Total side bone	2012	1701	2226	1863	2315	3685	3643	3650	4075	4566	4395	5986	6767	9233	9984	10213	10485	14133	15121	24421	29264
Total side fat	287	183	362	302	273	469	735	484	1329	987	724	1732	4464	3155	3497	3396	4541	7868	6277	25041	33284
Total side miscellaneous	427	346	557	498	626	1104	996	979	1201	1158	1099	1539	2161	2590	2485	2451	2573	2645	4897	8219	8058
Total forequarter muscle	1908	1602	2424	2049	2639	4316	4636	4728	4892	5185	5044	6953	10665	16099	16656	14958	17671	29908	29057	86345	71863
Total forequarter bone	1087	923	1200	1008	1246	1944	1963	2008	2292	2510	2442	3469	3896	5450	5849	5964	6226	8848	8805	15595	18266
Total forequarter fat	100	81.2	142	150	126	244	340	235	671	486	369	896	2270	1666	1843	1881	2373	4785	3578	13447	15611
Total forequarter miscellaneous	242	202	252	282	306	587	525	623	561	632	535	744	1124	1321	1436	1325	1369	1407	2689	4040	3482
Total hindquarter muscle	1475	1259	1973	1684	2339	4224	4608	4434	4843	5289	5158	6478	10068	13760	14891	14140	15989	21733	25163	55795	44224
Total hindquarter bone	925	777	1025	855	1068	1740	1680	164	1782	2055	1952	2516	2871	3783	4135	4249	4258	5285	6315	8826	10998
Total hindquarter fat	187	102	219	152	146	224	395	249	657	500	355	835	2193	1488	1653	1515	2168	3082	2699	11594	17673
Total hindquarter miscellaneous	185	143	304	216	319	517	471	355	640	525	564	795	1037	1269	1048	1125	1203	1238	2208	4178	4575
Standard Muscle Groups																					
1. Pelvic	917	815	1305	1073	1425	2801	3069	2972	3039	3418	3231	4095	6272	8394	9546	9077	10103	14041	15988	35572	27544
2. Crural	210	171	246	235	286	496	524	564	560	595	553	755	1067	1423	1507	1381	1638	1981	2256	3813	4041
3. Spinal	321	248	369	339	505	785	853	818	943	977	1042	1377	2295	3029	3131	3009	3245	5074	5784	14771	10247
4. Sublumbar	87	76.5	119	102	155	259	270	257	296	340	329	418	625	805	936	863	894	1182	1588	2852	1936
5. Abdominal	192	170	261	209	306	562	637	572	721	780	807	929	1558	2609	2560	2322	3024	4253	3948	12500	10857
6. Brachial	421	355	516	438	548	918	1044	1030	1051	1131	1107	1469	2225	3074	3430	3138	3759	6311	6063	15980	13388
7. Antebrachial	137	111	167	148	178	294	305	327	321	324	286	437	585	784	852	728	906	1255	1252	2417	2528
8. Extrinsic	499	423	646	563	695	1249	1319	1329	1418	1399	1389	1788	3041	4963	4882	4197	5193	8651	8287	26200	23310
9. Intrinsic (neck)	391	297	486	407	473	719	752	827	817	945	908	1428	1968	3226	3095	2970	3168	7214	6301	20506	16215
10. Thoracic	206	192	277	215	301	454	468	463	516	562	546	731	1094	1548	1606	1409	1726	1676	2749	7528	6021
1. Pelvic																					
Tensor fasciae latae	32.1	26.0	46.6	35.2	50.3	111	109	115	138	147	144	175	248	353	362	387	395	723	759	1917	1454
Biceps femoris	174	163	262	210	287	617	609	637	618	692	634	808	1391	1803	2091	1943	2211	3139	3367	7910	6455
Semitendinosus	60.6	52	90.9	75.4	102	197	213	234	222	263	223	260	465	682	752	632	718	1091	1102	3980	2634
Gluteus medius	99.5	72	121	108	152	280	325	289	300	356	327	413	662	899	1137	1038	1089	1570	1905	4413	3126
Gluteus accessorius	7.7	7.0	15.8	10.0	12.6	25.2	22.9	25.5	26.5	24.8	24.5	39.8	62.8	74.6	73	102	98	142	159	334	255
Gluteus profundus	19.1	15	19.2	13.9	20.8	35.5	34.1	26.1	33.7	45.3	39.4	59.2	81.1	109	139	120	134	233	221	415	407
Gemelli	2.35	2.64	4.10	5.27	6.61	10.1	8.74	7.66	11.4	9.72	8.92	13.9	18.7	28.3	15	28.1	25.5	34	53.0	45	46
Sartorius	14.1	12.5	22.7	15.8	21.5	33.4	45.1	43.8	45.5	50.7	47.2	35.1	76.8	93.4	116	92.4	113	144	159	329	248
Gracilis	38.1	32	56.4	46.8	60.3	112	128	127	130	130	132	163	275	396	342	353	425	562	573	1381	986
Pectineus	20.2	18.5	24.1	22.2	32.4	56.3	56.3	53.5	54.2	66.6	65.2	87	125	165	180	184	205	288	367	493	429
Semimembranosus	151.1	133	19.5	175	230	494	543	504	587	587	588	722	1123	1380	1617	1670	1777	2004	2598	5246	4369
Quadratus femoris	4.8	5.0	5.10	2.65	4.52	5	5.55	6.47	9.01	7.44	9.92	12.3	13.7	28.8	66	19.8	31.3	69	32.8	216	127
Adductor	36.1	46.0	74.3	63.3	83.8	141	241	181	172	231	209	258	315	493	569	557	569	887	979	1866	1362
Rectus femoris	75.1	71.0	103	80.1	106	216	230	167	216	254	245.5	332	448	535	596	563	651	976	1181	2148	1902
Vastus lateralis	73.6	78.0	120	105	130	243	259	322	244	263	251	337	482	625	705	659	833	1052	1275	2469	2100
Vastus intermedius	23.0	26.0	28.1	24.4	30.7	83	71.1	76	76.7	70.4	88.1	126	117	259	273	210	256	414	327	477	514
Vastus medialis	37.4	30.5	38.6	37.6	41.4	63	91.9	74.5	106	115	86.7	110	136	141	204	226	222	257	415	781	511
Obturatorius externus (et internus)	22.8	18.0	28.1	21.7	32.7	35	49.4	52	52.7	64.4	67.9	89	134	214	212	203	194	334	368	654	489
Scrap	15.4	10.6	31.0	18.5	17.0	23.3	26.1	29.7	30.4	39.2	30.6	54.3	97.0	114	100	90.2	166	120	146	498	130

APPENDIX 4: MALE JERSEY CATTLE CARCASS DISSECTION DATA (g)

Identification no.	23	24	25	40	41	26	27	28	29	32	33	37	39	36	21	35	34	22	38	30	31
2. Crural																					
Gastrocnemius	79.6	64.5	89.8	90.8	105	204	222	238	220	240	238	307	450	609	626	554	700	811	930	1689	1605
Flexor digitorum superficialis	22.1	17.0	24.4	21.8	28.3	48.3	48.1	52.9	56.1	66.3	48.4	84.4	106	132	131	134	174	166	201	238	242
Peroneus tertius et extensor digitorum longus	32.6	27.5	42.8	34.1	39.7	63.1	76.4	71.1	69.5	72.1	65.0	94.5	145	184	180	178	194	278	317	564	726
Tibialis cranialis	7.59	5.5	6.61	8.76	9.46	13.8	14.5	15.6	18.9	14.1	15.8	19.3	27.0	29.8	44.5	33.6	41.3	45	46.3	97	92
Peroneus longus	5.13	4.5	5.37	5.71	6.80	15.7	12.1	15.4	13.6	12.4	10.3	15.6	22.9	31.7	29.5	35.0	28.7	35	48.7	90	83
Extensor digitorum lateralis	13.9	7.0	11.9	12.3	15.0	20.3	25.6	23.4	19.8	24.2	25.5	33.9	46.1	59.4	79	69.5	75.6	101	100	206	229
Popliteus	11.2	8.0	11.0	15.1	20.1	30.9	35.2	41.4	36.1	36.1	42.7	44.5	67.2	84.9	61	75.5	91.7	128	151	233	265
Flexor digitorum profundus	34.5	33.5	50.3	45.2	59.9	94.9	88.0	99.7	115	123	103	156	195	282	331	290	326	381	454	661	774
Scrap	2.185	40	3.73	1.74	1.73	5.12	2.08	7.06	10.57	6.52	3.5	0	7.0	9.98	25	10.73	6.82	36	6.5	35	25
3. Spinal																					
Longissimus thoracis	80.8	77	112	91.6	147	259	272	296	251	262	260	370	681	799	990	892	962	1405	1574	4347	2870
Longissimus lumborum	81.8	54	100	98.7	148	208	243	217	315	320	332	407	776	1016	962	1014	1082	1453	1828	4388	2430
Iliocostalis thoracis	17.7	15.5	24.4	19.6	21.3	42.8	35.9	38.8	36.9	41.0	43.3	68.0	96.8	152	148	134.6	132	295	272	893	658
Iliocostalis lumborum	11.1	7.5	6.35	4.55	6.46	5.34	8.12	12.1	5.88	9.18	9.39	14.2	23.7	37.4	19.0	17.5	41.6	52.0	32.5	55.0	102
Multifidis thoracis	22.9	14.0	9.65	15.1	31.7	36.2	36.4	23.3	43.1	55.4	31.2	93.0	98.0	128	96.0	151	104	299	304	588	319
Multifidis lumborum	12.5	15.0	19.0	17.5	22.0	34.0	36.4	31.3	48.9	51.6	50.3	65.0	64.1	137	114	159	163	178	214	543	477
Spinalis cervicis et thoracis	56.6	50	67.6	69.0	93.0	144	161	135	159	152	216	250	391	523	544	468	582	1032	1195	3116	2721
Sacrocaudalis ventralis	3.09	1.6	2.95	1.50	1.00	4.14	3.84	3.40	5.21	4.04	8.30	6.40	12.7	21.9	14.0	18.2	26.5	24.0	36.1	50	52
Sacrocaudalis dorsalis	4.24	3.3	9.12	7.93	11.8	17.7	17.4	21.6	24.3	22.6	29.3	36.3	40.9	61.3	58.0	62.4	39.5	96.0	118	208	144
Scrap	30.1	10.7	17.8	13.8	22.2	33.6	39.1	39.2	53.6	58.7	61.6	67.4	110	152	184	91.8	112	239	209	583	474
4. Sublumbar																					
Psoas minor	12.6	8.5	13.9	10.3	18.1	30.9	28.8	35.6	30.0	46.0	30.4	49.3	68.7	79.3	109	131.5	100	137	157.9	327	151
Iliopsoas	69.0	64.0	95.5	86.3	126	216	226	211	[illegible]	276	276	325	515	655	777	671	726	961	1273	2375	1678
Quadratus lumborum	5.33	4.0	9.86	5.80	11.3	12.8	15.3	10.8	17.3	18.0	22.6	44.5	41.3	70.8	50.0	60.9	68.3	84.0	157	150	107
5. Abdominal																					
Cutaneus trunci	34.2	29.5	52.2	37.2	42.8	120	125	106	130	137	145	132	363	460	434	414	564	857	681	2581	2442
Rectus abdominis	60.9	47.0	62.2	49.9	81.7	137	158	151	172	189	185	222	349	616	464	518	641	901	1176	3030	2426
Obliquus externus abdominis	47.9	41.5	72.4	55.5	68.8	125	145	126	152	171	185	181	333	580	688	561	717	993	661	2654	2376
Obliquus internus abdominis	13.6	24.0	35.6	36.1	62.0	103	122	101	147	149	157	204	283	527	472	456	646	837	791	2209	1925
Transversus abdominis	35.4	28.0	38.6	30.9	50.6	72.9	84.3	86.2	117	131	133	188	227	426	501	373	456	665	639	2026	1688
6. Brachial																					
Deltoideus	16.6	16.0	18.6	19.5	19.7	38.2	42.4	42.7	47.0	41.0	48.5	55.0	97.5	144	149	114	150	240	305	826	686
Infraspinatus	68.0	54.0	80.8	69.5	89.5	143	175	167	173	190	175	267	368	472	595	553	644	878	1008	2805	2129
Supraspinatus	58.7	51.5	67.2	61.1	83.0	134	136	148	133	163	141	205	336	383	415	419	507	840	758	1750	1527
Coracobrachialis	5.17	4.00	6.15	4.63	7.53	12.2	10.0	7.88	12.9	9.33	9.68	16.0	29.9	31.0	46.0	36.9	54.4	76.0	77.3	155	131
Subscapularis	41.0	30.0	46.9	44.8	49.6	79.3	74.2	88.5	79.3	105	90.0	140	246	342	356	376	372	834	753	1908	1505
Teres major	13.9	16.5	19.0	15.6	22.4	34.5	43.9	35.0	48.7	47.5	54.1	64.0	90.0	145	133	130	128	241	289	611	407
Biceps brachii	22.5	17.5	28.8	24.5	31.4	54.4	66.5	54.9	59.2	62.5	63.4	97.0	112	174	199	176	218	356	331	606	542
Teres minor	9.33	11.0	10.9	8.56	12.05	20.2	17.0	16.5	16.9	20.4	16.3	28.0	40.4	48.9	62.0	49.3	68.2	196	95.7	362	184
Tensor fasciae antebrachii	4.88	5.50	7.36	5.19	5.44	12.7	12.3	17.2	15.5	14.9	16.2	12.0	18.9	43.6	43.0	47.6	35.8	76.0	71.5	219	264
Triceps brachii: Caput laterale	29.1	31.0	29.0	28.6	33.2	62.3	67.4	69.7	70.6	75.1	72.9	84.0	131	181	177	159	229	359	313	770	624
Caput longum	108	82.0	137	114	144	247	302	288	295	287	309	367	613	849	970	830	1034	1876	1679	5108	4438
Caput mediale	4.99	4.00	5.42	6.82	6.74	11.1	9.26	9.75	8.35	17.4	13.9	20.0	24.5	46.9	35.0	26.0	31.4	30.5	41.2	76	69
Brachialis	23.1	19.0	28.6	21.6	29.3	47.1	51.5	52.9	57.4	63.6	60.5	73.0	103	122.6	163	143	159	229	224	461	456
Anconeus	6.63	4.0	14.1	4.59	5.60	10.3	9.63	10.5	14.8	12.2	13.5	13.50	30.6	23.8	37.0	31.4	53.5	38.0	41.5	86	171
Scrap	10.5	9.0	16.4	8.61	8.36	11.3	26.1	21.7	19.2	21.2	21.8	27.9	26.6	66.8	50.0	46.6	74.3	40.0	76.1	237	255

APPENDIX 4: MALE JERSEY CATTLE CARCASS DISSECTION DATA (g)

Identification No.	23	24	25	40	41	26	27	28	29	32	33	37	39	36	21	35	34	22	38	30	31
7. Antebrachial																					
Extensor carpi radialis	41.8	29.5	45.3	43.8	49.6	73.8	82.0	89.8	76.1	79.1	77.1	100	156	242	212	199	246	366	373	875	840
Extensor digitorum lateralis	7.63	6.00	13.3	8.15	9.29	11.5	15.9	16.4	15.0	13.8	15.6	19.1	27.0	34.9	45.0	33.3	39.3	61.0	57.4	124	159
Extensor digitorum communis	5.22	11.0	15.2	14.4	13.3	23.7	23.2	25.8	24.3	23.4	23.9	32.3	44.2	55.4	57.0	55.4	62.6	95.0	91.1	202	256
Abductor pollicis longus	1.75	1.00	2.03	1.72	1.37	2.45	3.74	3.25	2.36	3.46	2.53	3.64	1.95	1.39	8.00	8.08	10.4	6.00	8.53	18.0	28.0
Ulnaris lateralis	14.2	11.5	18.0	16.1	17.4	34.8	35.2	34.6	38.3	34.7	29.6	50.6	70.3	82.7	99.0	82.4	88.9	136	142	302	264
Flexor carpi ulnaris	4.69	7.50	9.31	6.69	8.81	17.4	15.2	19.1	16.4	20.8	13.8	25.3	23.3	40.4	48.0	37.0	45.8	67.5	62.1	98.0	111
Flexor carpi radialis	6.29	7.00	7.51	6.22	8.94	11.1	11.8	13.1	12.2	13.0	12.1	17.0	22.2	40.0	39.0	31.2	41.1	39.0	46.7	76.0	91.0
Flexor digitorum superficialis	17.1	14.00	19.8	17.9	26.9	47.1	38.9	42.7	48.5	45.5	38.5	72.6	86.8	93.1	137	97.8	133	157	153	262	207
Flexor digitorum profundus:																					
caput ulnare	5.65	4.50	5.55	4.90	7.24	12.8	11.9	15.1	14.7	11.5	12.0	16.6	22.9	36.0	37.0	34.1	53.5	60.0	55.7	113	136
caput radiale	1.47	1.50	1.61	1.05	1.86	2.81	3.88	2.84	2.28	2.83	2.17	2.48	3.93	2.38	7.00	7.22	4.61	11.5	12.4	12.0	21.0
caput humerale	26.2	18.0	28.8	26.9	33.4	54.1	61.6	64.7	70.9	73.3	60.0	97.9	126	155	157	141	181	248	246	323	407
Scrap	2.85	0	1.17	0	0.4	2.70	1.77	0	0.66	2.53	1.04	0	0	0	6.04	0.99	0	8.0	4.56	12.0	8.00
8. Extrinsic																					
Trapezius pars cervicalis et thoracis	39.3	31.5	51.8	41.1	47.8	86.3	100	82.0	102	86.1	95.0	111	211	319	384	293	307	695	493	2668	2466
Brachiocephalicus	55.0	54.0	86.1	70.3	75.3	120	116	145	117	140	115	152	309	450	411	340	485	785	700	2573	2460
Omotransversarius	17.7	15.0	17.9	11.6	26.8	35.5	33.7	42.0	63.0	36.8	51.4	44	98.5	104	151	134	142	361	338	1063	860
Rhomboideus cervicis et thoracis	50.0	40.0	62.5	51.8	69.4	109	98.9	104	125	106	112	156	234	455	399	370	502	962	867	3189	2384
Latissimus dorsi	65.4	48.5	81.5	67.5	78.6	167	174	168	182	186	182	200	408	677	586	505	670	1011	958	3432	3009
Serratus ventralis cervicis et thoracis	113	87.0	131	138	186	319	340	324	375	390	372	611	835	1284	1391	1231	1440	2338	2455	6377	5577
Pectoralis profundus	101	101	141	131	156	305	340	359	336	335	347	371	667	1132	1123	885	1176	1611	1688	4726	4743
Pectoralis superficialis	56.7	46.0	72.9	51.1	55.0	106	115	104	117	118	114	143	279	542	436.5	439	471	888	788	2172	1811
9. Intrinsic (neck)																					
Sternomandibularis	14.5	17.0	23.7	19.6	19.2	27.4	32.9	43.3	38.5	36.0	40.9	54.0	96.1	176	131	117	127	334	250	1096	970
Sternomastoideus	23.9	17.0	27.5	23.3	27.5	36.1	35.2	51.6	40.5	57.8	45.5	81.0	107	139	202	137	168	518	224	652	620
Sternothyrohyoideus	9.94	6.00	7.54	14.1	17.5	12.3	12.9	16.4	11.4	18.6	27.7	32.0	43.9	76.4	38.0	55.1	42.4	94.0	122	365	281
Omohyoideus	1.50	0.75	2.30	3.06	1.47	1.09	1.79	2.35	2.00	3.39	6.29	8.93	12.0	30.3	7.00	4.53	23.5	16.0	41.2	113	34
Splenius capitis et cervicis	32.0	22.0	41.5	30.3	32.6	53.7	57.4	58.9	55.7	62.3	52.5	89.0	166	355	283	318	303	919	840	3561	1950
Longissimus cervicis	19.6	15.0	23.4	19.5	23.2	31.3	36.9	30.6	38.0	32.5	32.3	64.0	82.3	152	167	163	128	373	326	900	937
Longissimus capitis	13.0	11.0	18.4	16.5	16.4	28.4	27.2	24.7	26.8	26.4	27.2	38.0	61.0	109	88.0	83.9	116	301	228	936	808
Longissimus atlantis	1.50	1.50	6.81	3.98	1.48	3.82	3.51	8.75	6.30	4.55	5.96	11.0	19.7	25.0	44.0	30.7	59.3	115	60.1	183	115
Semispinalis capitis, cervicis et thoracis.	75.4	60.0	91.0	83.3	87.6	147	146	156	179	183	177	252	379	733	569	592	539	1501	1270	5418	4056
Scalenus doralis	6.62	9.00	12.7	6.81	12.6	18.5	27.7	29.0	20.4	24.7	35.3	37.0	43.3	94	91.5	53.6	83.2	302	153	1190	580
Scalenus ventralis	19.9	10.5	15.1	25.1	21.3	45.7	44.0	39.9	38.4	44.8	41.8	53.0	109	103	157	118	143	251	289	947	502
Intertransversarii cervicis	24.2	22.5	21.8	26.7	28.6	53.0	45.6	39.4	52.2	62.2	38.0	85.0	86.6	158	135	164	213	233	341	654	963
Intertransversarii longus	10.1	7.00	21.6	9.39	23.6	21.9	24.7	26.7	24.3	30.1	34.1	47.0	64.3	121	80.0	109	140	198	200	652	474
Longus capitis	15.0	10.0	16.8	11.9	14.3	17.4	18.8	21.3	30.1	33.5	31.1	59.0	88.7	109	99.0	122	104	299	228	448	307
Longus colli	20.7	21.0	17.0	31.3	45.7	61.4	44.6	60.3	70.6	80.5	73.1	124	151	221	286	217	252	524	615	1033	1122
Obliquus capitis caudalis	16.0	12.5	17.0	15.5	19.2	31.0	33.9	35.6	40.5	43.0	37.2	57.0	76.4	122	125	133	132	302	258	623	585
Obliquus capitis cranialis	4.96	6.00	5.55	5.96	8.08	12.4	11.6	17.9	16.2	18.0	14.4	22.0	21.8	28.3	50.0	42.5	42.3	37.0	44.5	93	93
Rectus capitis dorsalis major	11.0	3.50	9.69	7.86	8.40	10.3	10.6	14.8	15.4	17.6	17.7	20.0	30.2	51.1	37.0	39.4	44.1	79.0	83.2	226	215
Rectus capitis dorsalis minor	8.05	2.00	3.31	1.11	1.57	4.76	6.62	2.40	1.82	2.81	2.06	5.00	9.11	6.44	8.00	7.08	4.19	10.0	15.5	24	29
Rectus capitis ventralis	2.00	3.00	1.63	2.65	2.51	2.43	4.78	2.53	8.32	4.09	5.01	26.0	10.1	18.1	12.0	16.4	14.4	38.0	51.2	40	62
Rectus capitis lateralis	1.5	1.50	5.79	4.16	7.67	9.81	10.1	7.48	9.88	12.1	10.4	11.0	21.5	63.9	10.0	25.2	47.4	32.5	35.4	120	115
Multifidis cervicis	10.4	11.0	14.5	15.7	17.6	24.7	33.5	49.1	39.9	37.1	25.1	36.0	72.8	74.6	129	103	155	166	181	432	597
Scrap	50.4	28.0	81.7	29.0	34.9	64.2	81.0	87.1	100	110	28	225	215	257	346	318	285	57	442	800	100

APPENDIX 4: MALE JERSEY CATTLE CARCASS DISSECTION DATA (g)

Identification number	23	24	25	40	41	26	27	28	29	32	33	37	39	36	21	35	34	22	38	30	31
10 Thoracic																					
Interspinales	12.0	11.0	16.7	9.96	15.6	27.7	17.1	20.1	21.8	22.1	21.2	30.0	37.2	79.7	57.0	84.5	68.4	94.5	58.8	347	99
Rectus thoracis	3.82	3.00	6.45	5.56	6.88	9.80	9.67	10.4	11.5	12.9	14.8	15.4	27.6	39.1	44.0	35.3	37.7	84.0	70.6	190	160
Serratus dorsalis cranialis	3.99	7.00	14.2	4.85	8.19	6.85	8.96	10.7	8.72	12.0	9.76	14.8	21.4	46.6	29.0	38.7	42.1	51.0	73.8	144	237
Serratus dorsalis caudalis	4.30	2.00	5.85	4.02	7.74	8.14	10.6	8.42	12.4	8.54	10.4	16.1	28.7	16.9	42.0	21.5	38.3	22.0	19.8	179	181
Retractor costae	3.60	3.00	2.43	2.63	7.40	6.89	4.17	8.70	6.89	5.54	5.05	9.74	9.17	21.3	29.5	25.6	21.7	44.5	49.6	147	77
Intercostales	112	105	140	128	167	251	259	268	252	303	305	418	526	866	874	825	968	1600	1555	4204	3465
Transversus thoracis	6.70	8.00	9.22	8.30	8.95	15.2	15.3	14.9	15.5	21.3	26.9	26.0	46.6	61.2	46.0	61.3	73.9	137	100	258	182
Diaphragma	34.0	36.0	50.0	36.0	61	88.4	105	92.5	134	133	110	181	228	361	424	269	408	791	533	1834	1130
Scrap	25.9	17.5	32.2	15.9	18.6	40.2	37.5	29.7	42.1	43.6	42.7	20.0	168	56.1	51.0	47.1	67.6	211	228	205	490
Muscles of the Jaw																					
Masseter	23.9	20.1	22.8	20.8	22.7	48.4	50.6	48.6	68.6	81.5	82.9	117	141	210	305	229	282	396	418	536	573
Digastricus	3.78	4.01	5.00	4.78	6.07	9.98	10.6	9.96	9.51	11.5	11.9	16.7	17.4	45.4	34.0	34.3	40.9	51.0	43.0	87.0	62.0
Temporalis	8.45	5.23	5.67	2.98	9.47	20.3	21.4	15.8	30.5	31.2	31.5	40.3	55.8	63.4	119	86.5	102	179	116	197	285
Pterygoideus medialis	4.85	4.08	4.59	4.21	4.50	6.76	7.53	12.0	15.9	20.4	14.4	40.7	23.5	34.0	48.0	36.1	45.4	112	56.0	72.0	101
Pterygoideus lateralis	3.75	7.12	7.24	4.95	5.60	20.6	12.6	8.52	11.1	19.1	19.1	20.	22.2	75.8	62.0	51.0	68.4	125	105	166	100
Vertebrae (whole)																					
Cervical 1	44.3	41.8	53.3	44.1	54.6	86.3	86.0	88.4	98.4	105	109	146	164	233	261	282	243	370	352	602	792
2	58.4	55.0	67.7	55.0	68.2	103	104	108	113	119	117	155	167	231	269	268	228	395	360	613	838
3	38.7	32.0	45.5	38.7	48.8	66.8	70.0	73.5	76.7	80.3	77.6	105	114	163	195	200	171	304	268	559	690
4	41.0	37.7	48.8	40.6	51.0	75.5	73.7	75.1	85.4	86.0	81.5	118	121	166	201	203	185	319	284	580	699
5	39.2	35.8	49.3	41.0	52.4	74.4	75.9	77.1	83.6	92.4	86.5	124	138	177	216	217	203	335	309	592	696
6	39.5	38.9	54.9	44.9	55.5	76.5	79.2	82.7	85.5	94.7	91.4	124	138	201	225	226	221	364	319	631	782
7	33.9	32.8	41.2	34.5	44.6	67.8	63.3	69.6	70.4	80.6	74.5	103	120	192	174	193	181	296	284	561	653
Thoracic 1	38.2	33.7	42.3	39.5	46.3	67.4	66.3	70.1	75.5	82.6	85.5	125	147	230	227	217	231	371	334	655	761
2	34.8	28.4	36.2	31.4	40.6	60.5	61.0	61.5	69.2	75.6	78.1	115	133	191	193	198	203	323	297	567	734
3	31.9	25.3	32.2	28.2	36.7	56.1	57.3	56.7	62.8	74.3	73.1	110	128	167	186	178	194	296	281	537	659
4	27.3	24.8	31.7	25.8	34.4	53.9	52.9	55.5	59.7	68.8	68.9	105	118	156	176	170	187	278	266	519	600
5	26.9	23.4	28.1	24.8	33.5	49.7	51.4	51.4	57.2	65.8	67.3	103	120	151	165	161	180	258	261	494	581
6	24.8	21.7	25.7	22.8	31.3	45.3	47.8	47.6	54.4	61.8	63.2	94.2	109	142	152	149	160	229	232	455	538
7	23.3	21.1	25.0	22.2	28.3	42.9	44.1	41.5	48.4	55.2	55.4	83.7	97.3	128	139	129	136	199	200	369	451
8	22.1	20.1	22.3	21.7	27.9	40.8	39.9	39.9	44.2	50.6	51.5	77.0	91.0	112	121	113	124	170	178	347	390
9	22.8	18.7	22.7	20.7	26.6	39.0	38.5	37.4	43	47.6	49.2	71.7	82.8	107	113	105	113	151	167	299	353
10	20.4	18.9	22.0	18.3	26.8	38.6	38.4	37.2	40.3	44.8	45.8	69.6	79.5	97	108	104	105	136	149	260	324
11	20.7	18.3	22.2	19.7	26.7	38.1	36.0	38.3	38.8	44.2	43.9	71.4	81.6	97	111	110	110	140	159	265	322
12	24.1	21.2	23.1	19.2	26.4	42.9	43.5	42.6	42.4	48.2	53.7	77.3	85.5	106	114	110	114	157	164	305	421
13	25.4	23.5	26.9	21.1	29.2	42.9	45.1	44.5	47.8	53.5	54.7	75.8	88.2	112	128	125	126	169	183	323	466
Lumbar 1	28.3	31.0	31.2	24.7	33.4	53.8	53.0	49.6	53.0	60.3	58.4	89.4	101	129	146	125	140	206	214	412	489
2	29.3	24.5	35.6	28.5	37.0	59.7	61.1	55.3	57.7	67.3	67.3	99.2	113	146	170	159	163	235	257	447	556
3	34.4	31.0	38.0	30.8	39.2	63.0	62.5	60.8	62.1	72.3	71.1	103	118	161	177	174	172	261	266	508	626
4	34.0	29.5	37.5	33.3	41.1	64.5	62.3	60.6	64.8	75.8	74.2	103	119	165	174	191	171	271	268	519	632
5	33.1	29.5	36.1	32.1	41.3	65.2	64.1	59.4	67.4	77.2	77.1	100	121	173	183	200	178	287	277	501	615
6	34.9	29.5	35.9	32.3	41.1	61.1	60.9	61.8	69.6	78.1	79.3	101	116	178	176	196	186	277	275	496	592
Caudal 1	5.44	5.50	6.83	6.82	6.90	10.9	11.9	10.9	14.3	15.3	12.8	19.7	28.7	30.2	32.0	32.0	33.7	53.5	50.6	88.0	116
2	4.30	5.00	6.73	6.29	6.05	9.55	10.6	10.1	12.2	14.3	12.3	17.4	23.2	27.4	29.0	27.5	29.5	48.5	48.8	80.0	102
Sternum & costal cartilage	142	124	168	144	188	305	324	308	452	458	490	642	748	1040	1134	1256	1217	1662	1667	2300	3315
Total rib	207	186	216	182	212	338	345	355	494	555	534	814	910	1417	1350	1485	1618	2529	2229	4844	5335

APPENDIX 4: MALE JERSEY CATTLE CARCASS DISSECTION DATA (g)

Identification No.	23	24	25	40	41	26	27	28	29	32	33	37	39	36	21	35	34	22	38	30	31
Rib 1	15.6	13.5	18.5	17.1	16.8	28.5	26.6	29.6	34.9	41.9	39.1	59.0	66.3	100	102	111	115	175	158	301	362
2	12.5	8.50	13.1	9.17	13.1	19.3	21.8	21.6	27.5	29.1	28.2	41.0	47.6	68.2	63.0	74.6	77.0	125	107	225	226
3	10.5	7.50	12.7	12.2	14.0	21.7	23.3	25.1	28.9	30.9	33.1	48.0	52.7	75.1	75.0	90.0	84.0	149	120	268	256
4	14.5	11.5	15.5	13.9	16.1	25.4	29.1	27.7	34.5	37.1	35.7	55.0	62.5	92.4	82.0	101	104	164	140	310	305
5	18.0	13.0	18.1	16.6	17.5	27.4	32.1	32.7	38.0	44.7	39.3	63.0	76.5	100	96.0	119	126	185	176	407	373
6	19.0	15.0	19.9	16.6	20.3	29.2	32.5	33.0	41.3	51.1	44.9	75.0	96.0	125	97.0	140	166	215	218	482	465
7	20.5	16.0	21.2	17.4	21.1	32.0	35.3	34.4	45.9	50.6	47.9	91.0	98.9	139	118	146	177	240	243	516	532
8	20.1	17.5	20.3	17.5	18.4	31.9	36.4	33.5	46.6	54.3	52.9	86.0	88.4	146	128	148	180	277	214	479	507
9	15.6	13.5	18.9	15.2	17.2	28.3	33.4	29.0	41.8	53.7	50.6	74.0	80.0	141	110	130	140	258	204	437	493
10	13.0	10.5	15.0	12.4	15.0	22.4	24.8	22.5	36.1	44.2	44.8	65.0	65.8	114	96.0	111	125	224	165	394	500
11	12.5	9.00	13.1	10.3	12.7	17.9	20.6	19.0	28.5	34.1	32.6	51.0	54.6	94.3	70.0	95.0	102	159	148	330	385
12	10.0	7.50	10.5	8.66	10.3	14.1	16.5	15.0	23.2	25.3	28.5	45.0	44.0	78.8	60.0	73.0	91.0	137	126	287	344
13	8.28	5.00	8.43	8.06	9.36	12.7	12.4	8.20	18.4	21.7	25.0	27.4	36.5	71.2	54.0	55	57.0	117	114	156	299
Mandible	181	171	183	155	196	228	251	246	311	380	355	552	534	742	875	847	1058	1441	1265	1727	2078
Scapula	72.2	59.0	76.9	68.0	83.5	135	137	135	158	179	170	245	296	419	458	446	510	746	810	1593	1664
Humerus	172	133	182	156	191	315	311	319	346	377	364	479	561	772	857	840	908	1096	1238	1750	2056
Radius and ulna	146	116	166	131	162	247	254	250	275	291	275	383	407	538	626	585	608	778	912	1208	1533
Carpal bones	30.6	27.0	36.6	28.3	36.7	61.6	60.9	64.8	60.2	64.0	62.8	80.3	88.8	109	126	114	125	142	160	201	243
Metacarpus	91.0	74.5	103	84.9	99.5	146	141	148	138	156	141	193	198	238	274	255	276	301	357	426	532
Os coxae and sacrum	317	261	347	282	391	632	626	591	749	912	863	1088	1285	1900	2019	2252	2228	2993	3532	5552	6686
Femur	237	198	268	219	280	482	457	455	482	557	533	652	747	954	1044	1071	1092	1263	1587	2005	2424
Patella	17.3	14.0	17.8	13.4	18.5	27.7	30.3	28.0	24.8	33.6	32.8	37.1	48.6	50.3	63.0	65.0	72.8	76.5	94.4	116	118
Tibia (+ fibula)	176	148	199	164	203	336	301	306	325	365	332	452	489	626	682	687	682	791	981	1167	1514
Talus	42.0	36.0	48.0	40.6	45.5	75.9	74.9	77.1	66.3	66.3	65.1	77.5	85.2	89.8	109	99.6	89.4	86.5	118	125	161
Calcaneus	40.9	36.0	41.6	41.1	41.2	70.2	70.5	70.4	64.1	76.7	66.8	89.1	97.9	113	139	147	139	156	182	210	280
Distal tarsus	26.4	20.0	27.7	23.2	26.4	48.2	48.0	47.4	40.9	46.9	42.8	57.7	62.9	71.3	90.0	86.9	88.1	82	100	112	148
Metatarsus	101	81.0	110	92.8	106	154	151	160	149	166	155	213	221	280	306	294	308	307	392	444	515
Total subcutaneous fat	32.6	12.5	23.0	26.1	8.66	26.9	40.6	20.1	108	55.0	40.2	78.3	537	253	264	214	533	1449	577	3209	3759
" intermuscular fat	90.4	55.2	107	100	86.0	140	212	130	431	338	234	694	1572	1287	1119	1635	1997	3179	2650	8646	11727
" perirenal fat	60.3	33.7	116	60.8	57.7	59.2	119	65.2	121	97.5	69.3	251	687	419	637	376	481	558	1000	5247	9440
" channel fat	16.7	7.09	14.9	8.31	12.5	23	56.3	32.9	131	61.2	28.2	101	343	163	168	153	200	238	181	742	1696
Cod fat	14.0	27.0	18.0	43.5	32.0	49.3	71.4	63.5	166	113	69.0	141	588	463	410	285	436	996	718	3949	3299
Cavity fat	9.20	8.50	13.8	5.99	3.88	5.72	24.2	15.4	35.2	17.9	27.3	29.0	126	62.4	267	40.4	83.1	586	253	1765	1079
Sternal fat	10.7	4.50	14.7	8.93	9.73	25.4	28.8	21.1	44.8	39.1	43.0	45.0	114	89.4	104	83.9	136	165	189	295	488
Fat on bone	57.0	35.4	45.6	44.2	49.9	114	167	112	216	231	180	357	449	370	477	530	641	649	643	1092	1703
Spinal cord fat	9.65	8.08	8.39	4.62	12.8	24.6	14.7	23.3	24.7	32.8	33.6	34.0	44.4	46.7	49.5	77.1	33.2	46.5	64.2	95.5	93.5
FQ subcutaneous fat	0	0	10.1	9.18	0	10.7	2.03	0	33.1	11.2	10.9	18.8	213	44.9	71.0	80.6	155	559	238	1014	1434
FQ intermuscular fat	51.6	28.9	59.2	62.2	46.6	76.6	103	66.4	254	166	113	408	928	777	701	1042	1258	2090	1739	5911	8182
FQ fat on bone	21.1	15.5	21.2	17.3	25.4	60.4	103	54.9	122	117	85.9	234	274	206	263	294	288	368	404	460	1081
FQ spinal cord fat	7.65	5.33	5.47	2.98	8.89	16.4	8.01	14.3	15.0	20.3	19.5	20.5	24.8	22.6	27.0	55.1	15.5	21.5	34.8	53.0	48.0
HQ subcutaneous fat	32.6	12.5	12.9	16.9	8.66	16.2	38.6	20.1	75.5	43.8	29.3	59.4	324	208	193	134	377	890	338	2195	2325
HQ intermuscular fat	38.8	26.3	48.5	37.8	39.3	63.5	109	64.2	226	172	120	286	643	509	418	593	738	1089	910	2735	3545
HQ fat on bone	35.9	19.9	24.3	26.9	24.5	54.4	64.2	57.8	93.5	113	94.2	122	174	164	214	236	353	281	239	632	622
HQ spinal cord fat	1.99	2.75	2.92	1.64	3.92	8.26	6.76	8.92	9.74	12.5	14.1	13.4	19.5	24.1	22.5	21.8	17.6	25.0	29.3	42.5	45.5
<u>FQ Subcutaneous Fat</u>																					
1. Trapezius	0	0	0	0	0	0	0	0	0.32	0	0.22	4.32	17.0	4.27	0	5.38	15.5	47	13.3	95.0	202
2. Thoracic limb	0	0	0	0	0	0	1.21	0	1.16	0.84	0.31	2.21	12.5	6.18	5.00	8.54	14.9	102	14.4	62.5	128
3. Latissimus dorsi	0	0	0	0	0	0.45	0.23	0	2.16	0	0.16	1.41	39.1	2.67	8.00	4.51	34.0	148	37.4	179	273
4. Cutaneus trunci-abdominal	0	0	0	8.18	0	2.85	0.59	0	2.45	0	0.70	0	58.8	8.85	22.0	26.3	24.0	143	46.1	406	266
5. Pectoral	0	0	9.09	1.00	0	7.38	0	0	19.2	10.3	9.46	8.41	50.8	22.9	19.0	35.7	48.8	119	72.5	181	506
6. Neck	0	0	1.04	0	0	0	0	0	7.76	0	0	2.49	34.6	0	17.0	0	18.2	0	54.8	89.5	59

APPENDIX 4 : MALE JERSEY CATTLE CARCASS DISSECTION DATA (g)

Identification No.	23	24	25	40	41	26	27	28	29	32	33	37	39	36	21	35	34	22	38	30	31
HQ Subcutaneous Fat																					
I Cutaneus trunci- tensor fasciae latae	8.46	8	7.13	5.75	3.42	9.95	21.3	10.4	39.5	21.0	17.9	31.1	136	131	130	92.8	150	328	162	804	814
II Medial aspect of pelvic limb	3.48	2	5.77	7.60	4.56	6.06	13.8	8.52	29.8	17.6	7.38	21.2	65.0	56.4	20.5	20.7	114	168	75.8	236	488
III Lateral aspect of pelvic limb	0.75	0	0	0	0	0	0	0	1.28	0.82	0	1.45	34.5	4.63	8.00	1.13	35.9	148	40.6	461	302
IV Abdominal	16.7	1	0	0.78	0	0.27	0.68	0	1.53	1.30	2.11	2.06	49.4	0	16.5	11.7	44.7	167	20.8	325	351
V Longissimus	1.33	0	0	0	0	0	0	0	0	0	0	0	17.6	0	2.00	0	8.42	36.0	6.71	208	202
VI Perianal	1.92	1.50	0	2.82	0.68	0	2.80	1.27	3.33	2.99	1.88	3.65	21.8	15.4	16.0	7.80	24.3	43.0	31.6	161	168
FQ + HQ Intermuscular Fat																					
1. Axial muscles	8.36	5.50	5.27	20.0	20.6	16.8	26.8	15.3	69.9	54.3	32.1	137	291	212	130	299	354	801	653	1554	2512
2. Extrinsic muscles	19.3	12.8	17.6	24.9	11.1	20.5	34.2	25.6	86.2	44.6	29.6	37.3	333	218	326	282	415	572	563	2365	2618
3. Intercostal	5.66	10.0	13.1	7.76	3.17	8.22	7.07	7.07	29.9	18.1	20.8	52.1	75.8	142	89.0	215	170	308	182	901	980
4. Abdominal	9.08	2.63	19.6	5.57	7.83	13.7	23.5	8.22	43.8	25.6	17.2	56.5	262	132	65.0	148	211	446	376	1487	2189
5. Sublumbar	4.06	3.78	5.20	4.99	4.13	7.71	9.61	11.9	24.7	32.9	15.6	50.7	90.3	59.3	36.0	93.3	100	120	144	375	597
6. Proximal thoracic limb	10.7	4.50	11.4	6.72	7.11	16.3	13.4	15.8	43.1	32.0	17.8	57.3	99.6	131	100	131	175	200	185	410	796
7. Distal thoracic limb	3.93	7.00	2.12	1.48	3.16	8.21	7.44	3.32	11.5	7.76	8.77	7.79	12.9	15.9	37.0	35.4	55.0	46.0	11.6	88.0	49.0
8. Proximal pelvic limb	21.7	15.0	24.3	21.8	22.6	36.6	71.6	29.6	133	91.2	72.6	161	359	298	257	334	419	558	440	1115	1519
9. Distal pelvic limb	7.59	4.00	9.04	6.82	6.28	11.8	18.6	13.6	38.2	32.3	19.2	34.9	46.9	77.0	79.0	94.3	95.3	128	91.6	351	467
FQ + HQ Bone Fat																					
1. Cervical, thoracic, lumbar	8.16	3.00	11.9	14.7	11.6	27.6	37.8	21.3	51.2	48.6	46.8	115	113	150	153	170	203	195	212	180	445
2. Sternum + rib	3.77	6.00	1.00	2.24	9.34	22.8	44.6	27.1	58.5	48.0	34.6	115	169	79.2	99.0	75.9	113	170	231	261	587
3. FQ long bones	11.0	6.50	11.3	3.71	6.28	13.6	26.9	9.74	23.9	26.3	22.5	28.3	33.6	2.22	62.0	59.7	52.5	74.0	26.8	82.0	168
4. Pelvic girdle + sacrum	4.99	1.00	2.82	4.30	3.70	7.13	10.6	12.0	8.60	16.2	14.8	32.5	39.0	50.0	30.0	46.7	88.0	40.0	69.1	223	179
5. HQ long bones	29.1	19.8	19.4	19.2	18.7	43.6	47.3	42.5	74.0	92.5	61.3	66.1	93.0	88.5	133	177	184	170	103	346	324
FQ Fascia, tendon + ligament	164	119	173	206	228	450	405	336	452	501	407	604	1001	1105	819	984	1143	1219	2247	3516	3089
HQ " " "	137	104	325	158	222	386	355	298	527	404	403	684	944	1139	763	948	1018	1085	1906	3069	3157
Ligamentum nuchae (C-T_1)	23.0	18.0	4.78	31.4	40.3	57.5	41.5	51.8	59.3	59.9	60.1	71.0	89.6	96.1	148	112	106	150	165	208	316
" " (T_1-T_{12})	10.0	9.00	3.80	25.6	21.7	25.6	25.6	28.2	38.8	32.1	36.4	53.0	76.1	74.7	86.5	98.5	95.0	91.0	137	97	113
Total lig. nuchae	33.0	27.0	8.58	57	62	83.2	67.1	80.0	98.1	92.0	96.6	124	166	171	235	211	201	241	302	305	429
Spinal cord	28.1	27.4	33.6	29.1	39.4	36.9	41.6	36.7	52.8	54.1	51.5	71.7	58.2	77.9	71.5	71.2	73.9	108	110	141	158
Heart	212	202	262	204	239	415	385	354	432	466	522	833	752	922	969	921	1320	1557	1387	4059	3329
Lungs	315	325	342	393	345	615	601	491	875	813	1525	1123	1662	1884	2114	2038	1955	2509	1798	4325	5739
Liver	552	451	566	551	928	1037	1135	903	1655	1783	1913	2433	2684	3114	2142	2787	3562	5125	4451	9753	9813
Spleen	102	64.0	73.0	71.0	125	188	212	187	221	220	192	216	285	396	311	359	418	811	463	1321	1428
Left Kidney	58.0	52.0	54.0	59.0	81.0	156	131	101	186	157	177	204	250	395	230	255	265	333	295	949	814
Right Kidney	55.0	54.0	54.0	67.0	81.0	166	132	103	183	180	169	177	222	325	217	272	273	341	325	829	720
Stomach	369	341	526	380	636	876	963	886	2010	3236	3001	5148	5300	7300	10900	11300	10400	12100	14300	25400	32955
Intestine	947	991	1255	1056	1840	2243	2158	1857	4682	6614	5479	7683	7945	9650	8200	8500	13450	11900	13450	18500	39886
Right testis	5.00	3.50	4.00	4.00	5.20	7.95	8.34	8.80	13.6	17.0	17.0	35.0	40.0	144	118	141	165	289	311	499	493
Left testis	5.00	4.50	5.00	4.10	5.20	7.50	8.41	8.71	13.1	18.0	18.0	33.0	36.0	154	112	141	183	271	336	477	589
Penis	22.0	27.0	49.0	18.7	20.4	28.4	30.8	30.7	39.9	48.0	44.0	102	136	313	290	393	518	475	505	579	881
Preputial mm	3.50	3.00	1.50	2.94	4.99	23.6	17.0	19.4	16.6	25.0	27.0	4.00	75.0	87.0	98.0	68.0	89.0	174	109	413	376
Retractor penis (L +R)	6.00	4.00	7.00	2.67	2.62	5.39	6.19	7.23	5.99	8.00	4.00	19.0	30.0	35.0	33.0	29.0	59.0	48.0	59.0	36.0	93.0
Right cremaster m	1.00	1.00	1.00	0	0.92	2.35	3.08	2.52	2.27	3.50	2.00	4.00	8.00	14.0	40.0	25.0	25.0	51.0	30.0	70.0	67.0
Left " m	2.00	1.00	1.00	0	0.60	1.95	1.47	1.73	2.62	5.00	2.00	4.00	7.00	13.0	40.0	25.0	30.0	50.5	27.0	75.0	57.0
Ischiocavernosus (L + R)	4.00	3.00	3.00	3.10	3.43	10.3	8.90	15.7	4.69	8.00	8.00	21.0	80.0	162	198	151	256	316	306	359	594
Bulbospongiosus (L + R)	11.0	7.00	15.0	2.70	3.27	9.83	19.3	13.6	8.71	19.0	12.0	16.0	38.0	60.0	89.0	59	126	91.0	106	174	199
Urethralis	0	0	0	6.50	3.53	0	0	0	17.2	19.0	14.0	19.0	32.0	65.0	0	0	105	125	83	140	99
Coccygeus	0.82	1.60	1.53	1.39	4.12	4.61	2.70	5.09	5.47	3.31	3.89	4.84	14.7	15.1	17.5	13.0	16.4	25.5	22.1	88.0	50.0
Levator ani	0	0.60	0	1.82	2.51	1.69	3.84	1.99	2.19	2.71	2.82	5.43	11.0	16.5	25.0	11.9	10.0	21.0	29.6	21.0	37.0

APPENDIX 4: MALE JERSEY CATTLE CARCASS DISSECTION DATA (mm)

Identification No.		23	24	25	40	41	26	27	28	29	32	33	37	39	36	21	35	34	22	38	30	31
LINEAR MEASUREMENTS																						
1. Crown-rump		680	680	790	760	805	850	860	860	850	1045	1090	1190	1210	1340	1290	1365	1355	1620	1620	1920	2080
2. Minimum neck girth		415	370	410	395	410	470	515	480	490	440	498	555	640	780	760	700	750	855	880	1135	1150
3. Height at withers		680	650	690	730	750	770	770	790	870	910	895	970	1040	1060	1020	1100	1070	1220	1330	1390	1350
4. Width between tuber coxae		150	150	160	145	180	230	240	230	240	260	260	310	380	420	260	420	430	485	500	620	580
5. Width between tuber ischii		50	35	40	30	35	47	48	48	60	55	57	65	80	80	110	85	95	110	110	210	120
Length of cervical vertebrae		188	200	214	192	208	249	240	247	269	288	272	323	315	354	355	375	400	460	470	480	550
" " thoracic "		288	299	315	290	315	377	364	366	412	447	4444	509	500	557	604	560	583	662	677	868	841
" " lumbar "		146	143	156	145	165	184	181	188	209	225	233	262	254	300	316	310	309	340	340	385	423
" " sacrum		109	93	103	93	128	124	122	125	173	190	200	183	186	257	208	262	237	225	245	267	290
Total length		732	735	789	722	817	935	907	926	1063	1151	1149	1278	1255	1468	1483	1507	1529	1687	1732	2000	2104
Length of caudal vertebrae		43.0	42.0	44.7	39.3	43.8	5.10	49.3	52.0	58.0	60.0	60.4	70.5	58.7	83.8	82.0	86.9	79.5	100	98.9	112	120
Length of rib 1		120	123	124	125	118	142	141	145	151	160	170	185	190	219	230	240	230	279	285	330	356
" " rib 2		186	178	183	176	187	199	203	211	232	252	260	307	297	311	368	365	370	460	415	510	480
Scapula :	length	174	175	186	185	193	220	234	223	242	247	253	284	297	331	32.8	356	363	436	421	515	510
	width (distal neck)	22.6	22.0	20.5	19.3	24.0	27.8	23.9	24.7	16.5	28.6	28.3	35.2	34.5	37.3	44.7	45.8	47.5	48.6	52.6	65.3	69.7
	width (proximal)	84.7	78.5	89.4	81.3	88.9	110	112	106	115	113	117	139	137	156	188	170	178	230	205	225	240
Humerus	length	154	149	162	156	167	187	183	189	199	206	203	221	229	226	260	256	265	310	293	332	340
width	Deltoid crest	66.9	55.3	66.4	70.7	78.8	84.5	85.9	85.1	92.5	87.2	94.0	101	102	117	120	117	125	116	138	173	185
	mid-shaft	18.3	20.7	18.4	18.3	19.8	22.8	22.9	21.9	22.5	23.0	30.4	25.7	27.2	28.4	32.3	29.6	31.7	32.0	36.0	42.8	47.0
	proximal	59.4	54.4	62.7	55.5	61.0	77.5	75.6	72.5	78.1	79.0	80.0	86.2	92.7	104	106	110	116	118	121	138	142
	distal	52.4	47.2	55.2	54.5	54.2	68.5	66.1	65.3	65.1	65.7	65.6	62.5	72	76.2	80.3	76.4	77.7	71.3	78.7	79.6	86.9
Ulna	length	187	180	198	193	208	225	227	232	240	244	247	273	260	295	316	318	325	355	358	377	394
	width	10.8	8.20	12.6	9.30	9.80	12.0	13.6	12.4	13.2	10.9	12.4	12.3	16.0	17.8	18	12.2	17.3	13	16.8	20.1	22.8
Radius	length	157	152	162	154	166	179	178	188	190	192	196	210	208	235	242	246	237	285	278	284	303
	width	13.6	11.5	13.0	11.2	11.6	15.3	14.3	15.6	15.0	14.6	14.8	17.0	17.7	18.6	21.0	18.5	20.3	22.0	23.3	28.0	29.1
Metacarpus	length	144	142	151	150	154	166	160	168	163	166	164	175	176	181	189	192	176	188	200	192	210
	width	15.0	13.5	16.1	13.4	16.0	18.2	17.0	17.6	17.5	16.6	17.2	18.5	19.9	21.3	23.2	20.3	22.5	24.0	24.8	28.1	28.0
Mandible	length	183	175	184	177	185	203	211	208	219	238	231	262	256	285	354	309	306	304	345	399	385
	height	96.9	85.5	106	86.8	97.0	105	113	121	121	130	127	154	148	167	206	175	186	182	212	212	256
Os coxae	Betw. tuber ischii	32.1	28.0	34.9	24.3	30.5	54.0	48.2	46.9	53.9	53.9	54.7	63.6	60.0	86.5	102	93.2	87.1	100	108	102	136
	Betw. tuber coxae	137	129	136	135	143	168	180	168	194	211	215	252	267	301	329	324	340	410	396	488	505
	Conjugate diameter	73.7	68	84.3	74.6	81.9	87.6	89.2	86.9	106	113	116	114	120	161	145	173	144	175	174	191	183
	Transverse "	54.5	44.1	56.0	52.3	55.3	66.6	71.3	71.1	80.1	83.0	85.2	98.4	98.6	112	121	116	108	128	141	163	173
	Vertical "	59.0	53.3	64.3	60.4	63.0	69.5	67.5	69.0	72.0	75.2	79.3	95.4	85.8	103	116	115	114	130	120	158	159
Femur	Length	186	177	196	191	202	227	222	231	241	255	261	276	284	315	321	331	317	372	383	415	439
	width	17.0	16.6	18.2	16.8	19.4	22.7	22.0	21.0	21.5	23.0	23.2	25.8	26.3	29.2	33.0	29.8	32.0	31.1	33.6	45.4	41.0
Tibia	length	193	185	201	204	206	229	221	233	240	252	250	273	275	305	305	318	302	343	347	358	390
	width	16.3	15.0	16.2	14.8	16.6	19.8	18.7	16.5	19.1	18.3	18.5	22.4	21.7	23.7	25	23.8	25	29.9	27.4	30.6	32.8
Metatarsus	length	162	154	168	167	169	185	179	186	180	184	186	198	197	203	210	213	207	220	218	215	240
	width	15.8	14.6	18.0	15.2	15.7	18.7	17.7	19.1	18.3	18.8	18.2	21.0	23.3	23.0	24.3	23.5	25.8	25	28.0	29.5	31.2

APPENDIX 5: FEMALE JERSEY CATTLE CARCASS DISSECTION DATA (g)

*Age in days or number of incisor teeth in parentheses

Identification No.	2	3	4	5	6	7	8	9	10	17	12	18	1	16	11	13	15	14
Age*	1	1	1	38	38	42	139	141	145	(2)	(2)	(2)	(4)	(2)	(2)	(6)	(8)	(8)
Liveweight at slaughter	23200	19545	19545	54800	43100	45000	86364	85000	95455	117273	140000	172727	219023	181818	186000	295000	347727	413636
Empty body weight	22900	18765	19319	50933	40423	37356	72464	68241	79851	112705	121552	159377	200623	164368	168614	268895	321127	387986
Half carcass weight	6014	4988	5155	15702	12024	9922	18683	17042	20027	28017	36075	42796	63930	39318	41247	65585	80346	97743
Total side muscle + bone	5469	4438	4648	13450	10465	9100	16385	14780	17600	21180	26687	33801	49350	31384	33171	49186	58242	70439
Total side muscle	3596	2954	3057	9629	7621	6211	11416	10160	12500	15413	19994	25675	37451	22565	24391	38178	45781	54680
Total side bone	1873	1483	1590	3820	2843	2889	4968	4619	5065	5767	6692	8125	11900	8819	8779	11008	12461	15758
Total side fat	136	233	99.2	1249	784	112	1158	1116	1330	5333	7529	7111	12341	5586	5991	13498	18323	23464
Total side miscellaneous	408	316	408	1002	775	708	1139	1147	1116	1502	1859	1882	2287	2347	2084	2899	3780	3839
Total forequarter muscle	1918	1585	1659	4759	3764	3067	5736	4964	6150	7662	9764	12107	19440	11230	13023	19484	23688	28110
Total forequarter bone	1018	810	864	2134	1569	1559	2836	2623	2850	3326	3812	4600	6912	5054	5177	6474	7504	9393
Total forequarter fat	71.6	92.5	54.4	665	414	62.4	396	392	438	3030	3655	3729	6628	2929	3458	6924	8239	11578
Total forequarter miscellaneous	192	156	208	510	414	351	558	575	569	776	866	880	1029	1275	819	1447	1743	1752
Total hindquarter muscle	1677	1369	1398	4870	3856	3143	5680	5193	6366	7751	10229	13568	18011	11334	11367	18693	22092	26570
Total hindquarter bone	854	673	726	1685	1274	1330	2132	1996	2214	2440	2879	3524	4988	3765	3601	4534	4956	6365
Total hindquarter fat	64.7	141	44.7	584	369	50	762	723	889	2302	3873	3382	5713	2656	2533	6574	10083	11885
Total hindquarter miscellaneous	215	159	199	492	360	357	580	571	547	726	993	1002	1258	1071	1265	1451	2036	2086
Standard Muscle Groups																		
1. Pelvic	1058	860	883	3194	2576	2035	3530	3190	3985	4798	6152	8393	11315	7337	6658	11590	13246	15922
2. Crural	225	193	201	546	454	371	620	597	674	827	1081	1349	1709	1096	1123	1648	1998	2346
3. Spinal	331	273	293	931	678	606	1206	975	1310	1545	2197	2821	4296	2283	2445	3965	4809	5935
4. Sublumbar	108	74.3	88.2	285	223	199	344	325	396	513	657	930	1092	831	811	1185	1443	1567
5. Abdominal	228	192	175	663	570	409	981	919	1116	1156	1746	2094	3054	1639	2201	3462	4377	5519
6. Brachial	421	352	367	1051	808	695	1262	1126	1307	1788	2164	2627	4206	2590	3024	4418	4529	5839
7. Antebrachial	125	111	121	316	251	180	359	274	344	427	546	673	925	622	665	947	1102	1282
8. Extrinsic	491	413	428	1367	1076	824	1492	1290	1631	2157	2699	3456	5332	2990	3599	5422	6722	8018
9. Intrinsic (neck)	368	308	313	787	608	562	984	895	959	1340	1746	1951	3310	1908	2437	3207	4263	4867
10. Thoracic	237	174	188	484	373	327	634	562	699	859	1002	1377	2211	1265	1424	2330	2987	3382
1. Pelvic																		
Tensor fasciae latae	36.1	29.0	31.9	140	113	63.3	148	120	170	189	242	367	581	360	317	531	696	872
Biceps femoris	213	178	182	666	567	440	726	619	810	1047	1386	1811	2425	1522	1521	2488	2833	3148
Semitendinosus	71.0	57.1	56.1	222	192	147	247	220	276	300	415	653	760	458	499	836	1055	1248
Gluteus medius	103	83.3	84.1	336	235	216	368	338	413	551	710	889	1321	864	853	1390	1455	1906
Gluteus accessorius	10.3	7.83	9.56	26.1	18.9	19.9	35.1	32.0	36.0	45.0	59.4	126	128	61.8	60.6	102	166	206
Gluteus profundus	14.4	10.7	11.6	36.1	26.9	25.5	45.9	43.5	53.7	62.8	77.2	137	210	102	91.1	150	186	248
Gemelli	5.47	3.34	3.25	9.30	7.59	7.61	12.3	9.36	14.1	13.8	12.8	14.3	26.0	27.4	23.7	37.7	36.1	33.9
Sartorius	16.7	12.5	11.8	45.1	45.0	20.3	29.1	41.9	40.2	55.6	70.7	86.7	98.0	81.4	93.5	172	129	179
Gracilis	52.4	31.9	34.9	129	102	71.5	133	130	164	183	219	344	416	265	159	502	555	606
Pectineus	22.2	18.9	18.5	63.8	52.6	41.6	79.2	66.7	103	95.5	116	178	231	130	139	218	251	271
Semimembranosus	172	157	154	560	473	345	607	636	676	786	1008	1380	1792	1262	941	1834	2271	2560
Quadratus femoris	2.42	2.03	2.63	8.33	5.84	5.88	8.91	6.64	9.48	14.1	17.5	20.1	42.0	13.7	18.2	23.4	21.5	28.4
Adductor	65.8	47.7	55.8	191	127	137	233	143	282	282	369	488	720	469	426	754	655	948
Rectus femoris	76.9	58.7	68.8	238	181	140	241	240	286	334	441	557	791	550	528	847	930	1220
Vastus lateralis	93.2	70.5	71.3	272	223	178	278	243	293	388	459	663	878	587	640	802	944	1193
Vastus intermedius	38.4	41.6	33.3	86.2	54.3	64.7	103	84.0	110	153	180	210	337	199	212	247	304	317
Vastus medialis	26.0	23.5	24.6	76.2	79.6	60.2	107	101	110	136	136	216	276	165	209	245	306	386
Obturatorius externus (et internus)	28.5	17.9	23.6	63.3	48.3	37.9	85.7	78.0	91.5	99.0	128	183	253	178	116	281	312	375
Scrap	9.48	8.08	5.86	24.3	21.3	10.9	40.6	36.6	46.0	63.4	105	68.7	30.0	40.1	11.7	128	139	178

APPENDIX 5: FEMALE JERSEY CATTLE CARCASS DISSECTION DATA (g)

Identification No.	2	3	4	5	6	7	8	9	10	17	12	18	1	16	11	13	15	14
2. <u>Crural</u>																		
Gastrocnemius	88.9	69.7	79.3	229	195	157	263	239	288	346	435	557	693	444	488	640	820	935
Flexor digitorum superficialis	21.9	24.2	21.4	52.3	38.9	39.3	62.2	61.3	62.6	91.2	102	120	176	117	104	165	208	218
Peroneus tertius et extensor digitorum longus	32.5	27.2	27.7	72.1	61.4	49.2	81.4	74.2	86.3	110	149	137	251	135	139	244	249	349
Tibialis cranialis	8.40	6.24	5.39	16.1	12.1	10.8	11.9	14.5	17.8	17.7	29.9	32.9	38.0	27.0	11.8	37.8	42.0	47.6
Peroneus longus	5.87	4.08	4.31	12.9	16.7	7.59	9.75	13.2	14.3	16.0	18.6	26.8	36.0	17.8	20.8	30.3	34.0	40.6
Extensor digitorum lateralis	9.30	9.33	8.01	27.6	14.3	14.7	24.8	33.6	32.3	33.1	48.1	46.0	82.0	53.6	46.0	78.3	101	111
Popliteus	12.5	17.0	16.2	32.4	25.9	27.8	38.9	43.2	38.5	73.7	58.5	84.0	75.0	74.3	61.2	112	207	136
Flexor digitorum profundus	44.1	34.1	35.2	103	85.1	63.9	123	116	125	133	230	341	353	223	250	338	331	497
Scrap	2.11	1.78	3.31	0.95	4.23	0.78	4.12	1.97	9.49	5.78	9.84	4.90	5.00	4.76	2.79	3.26	6.76	11.1
3. <u>Spinal</u>																		
Longissimus thoracis	90.2	81.2	80.3	272	215	194	368	276	392	420	614	774	1125	640	706	958	1360	1487
Longissimus lumborum	84.0	71.6	79.0	308	223	171	360	303	436	532	759	945	1276	765	745	1432	1516	2045
Iliocostalis thoracis	19.5	13.8	15.1	38.1	27.5	27.0	50.7	41.2	55.2	57.7	96.3	95.5	194	73.5	117	163	205	274
Iliocostalis lumborum	5.91	4.58	2.48	3.75	9.14	2.47	11.6	9.57	13.5	14.0	16.5	21.1	25.0	14.4	22.9	32.8	40.7	48.7
Multifidis thoracis	12.5	14.0	17.3	47.1	38.2	29.5	66.3	40.1	59.0	91.7	105	150	164	135	109	202	263	275
Multifidis lumborum	17.4	7.58	17.0	39.4	27.4	30.1	51.0	50.9	50.4	69.8	111	160	172	127	105	215	282	339
Spinalis cervicis et thoracis	67.5	58.0	58.6	152	104	105	198	158	193	244	335	459	775	364	434	679	810	1063
Sacrocaudalis ventralis	1.67	1.47	2.08	6.40	4.15	3.83	5.55	8.43	8.59	4.27	8.55	14.6	17.0	12.2	16.5	17.4	22.3	25.0
Sacrocaudalis dorsalis	8.70	6.02	7.01	22.3	17.0	12.2	30.9	26.3	33.3	35.4	42.3	94.5	91.0	65.6	58.3	83.3	112	87.2
Scrap	24.4	15.0	14.6	40.8	12.7	29.4	645	62.1	68.9	75.3	108	106	457	84.4	131	180	197	291
4. <u>Sublumbar</u>																		
Psoas minor	13.1	7.75	11.2	39.7	28.8	21.3	37.3	37.8	40.9	49.2	67.9	78.8	130	113	67.4	121	171	130
Iliopsoas	89.3	61.2	70.0	235	183	169	279	265	330	417	528	774	917	659	671	959	1142	1319
Quadratus lumborum	5.77	5.28	6.92	10.3	11.8	8.87	28.3	22.3	25.7	47.3	61.1	77.4	45.0	59.2	73.5	105	129	117
5. <u>Abdominal</u>																		
Cutaneus trunci	39.4	33.7	34.8	142	121	78.7	166	143	180	232	304	384	518	277	402	589	755	1162
Rectus abdominis	58.5	58.5	47.6	164	154	96.1	246	241	293	335	388	462	768	334	429	749	942	1075
Obliquus externus abdominis	55.7	36.4	30.8	136	121	93.6	206	186	226	187	388	522	709	379	496	854	1041	877
Obliquus internus abdominis	39.4	35.5	33.9	124	91.6	80.3	190	196	237	220	372	433	563	361	511	701	937	1105
Transversus abdominis	34.9	28.3	28.4	95.1	81.1	60.3	171	152	178	180	294	292	496	286	363	568	702	1300
6. <u>Brachial</u>																		
Deltoideus	16.3	14.2	15.3	45.8	33.6	24.5	46.0	40.4	46.6	71.0	91.0	116	145	84.9	97.6	143	184	257
Infraspinatus	67.1	51.3	56.4	174	126	106	227	197	257	326	399	458	737	489	527	835	942	1056
Supraspinatus	64.1	55.5	59.8	150	113	107	185	164	205	275	302	382	615	351	476	643	621	744
Coracobrachialis	5.72	4.44	6.11	8.98	9.53	7.52	14.6	13.6	11.5	21.6	14.7	34.1	50.0	31.2	65.0	47.4	55.1	60.1
Subscapularis	42.6	30.7	30.4	95.6	59.9	63.4	121	102	128	140	212	290	420	274	251	491	535	625
Teres major	16.2	12.9	11.9	42.8	38.7	26.1	40.9	49.8	54.8	56.9	80.3	87.6	163	114	98.1	161	171	257
Biceps brachii	21.5	19.6	20.5	56.5	45.1	43.0	76.0	65.0	76.8	100	128	137	242	146	181	245	280	369
Teres minor	8.90	6.35	6.06	19.9	17.8	14.0	24.5	21.8	18.2	30.4	38.8	50.8	108	28.4	50.7	73.7	53.2	115
Tensor fasciae antebrachii	4.83	4.57	5.51	14.4	9.94	8.40	15.5	14.1	17.3	17.6	27.3	43.9	52.0	27.5	29.7	41.9	50.9	80.8
Triceps brachii:																		
Caput laterale	25.4	24.7	26.6	68.2	57.6	46.7	85.6	62.7	90.9	111	133	155	286	152	182	258	283	343
Caput longum	111	91.5	89.5	279	221	181	325	296	365	478	560	667	1116	702	812	1168	1276	1493
Caput mediale	5.76	4.76	7.74	13.4	8.68	11.3	159	11.9	19.1	20.8	29.7	29.3	28.0	25.5	24.4	33.6	41.7	42.4
Brachialis	19.6	20.7	18.7	51.8	45.0	33.3	59.2	59.2	61.9	80.7	95.9	113	161	110	134	173	196	244
Anconeus	5.69	4.06	4.68	10.6	7.77	8.59	11.2	11.0	16.2	18.6	13.3	26.6	33.0	19.1	26.2	42.7	50.3	42.1
Scrap	6.00	6.88	7.60	19.8	14.5	13.5	15.1	17.8	284	39.2	39.5	33.8	50.0	34.1	69.1	58.8	90.1	110

APPENDIX 5: FEMALE JERSEY CATTLE CARCASS DISSECTION DATA (g)

Identification No.	2	3	4	5	6	7	8	9	10	17	12	18	1	16	11	13	15	14
7. Antebrachial																		
Extensor carpi radialis	37.0	28.7	32.8	86.0	68.0	50.6	87.0	76.4	96.3	118	144	170	237	153	167	250	305	340
Extensor digitorum lateralis	6.52	5.76	6.33	12.9	11.5	8.39	13.6	13.2	17.4	16.7	28.3	36.7	45.5	26.4	27.0	47.5	59.4	55.1
Extensor digitorum communis	12.8	9.55	11.4	24.0	18.7	15.8	26.6	21.8	23.7	33.4	46.0	48.1	62,5	50.1	41.9	59.7	76.4	93.5
Abductor pollicis longus	1.54	1.05	1.16	2.53	2.86	1.57	4.22	2.38	2.89	3.23	4.08	6.66	5.00	5.07	4.25	6.63	10,8	12.2
Ulnaris lateralis	5.22	11.3	12.0	35.2	27.5	25.0	40.5	31.6	35.5	47.0	61.8	61.9	117	53.5	78.5	98.9	129	159
Flexor carpi ulnaris	6.42	5.39	5.85	15.7	12.4	10.9	19.9	12.9	19.0	23.0	27.9	35.4	49.5	35,8	28.2	50.9	71,6	68.2
Flexor carpi radialis	6.27	5.18	7.07	12.9	11.5	8.49	14.4	10.8	12.4	18.2	20.4	30.0	30.0	25.4	24.3	35.6	36.0	45.7
Flexor digitorum superficialis	16.7	14.8	16.9	47.1	34.0	29.4	54.5	44.8	49.6	64.0	73.0	103	135	92.6	160	139	152	169
Flexor digitorum profundus:																		
caput ulnare	5.77	4.56	4.36	11.9	10.8	7.89	11.4	10.2	11.6	15.5	22.4	38.9	42,0	36.4	32.3	47.4	51.0	59.4
caput radiale	0.79	0.87	0.47	4.15	2.64	1.33	3.00	3.08	2.66	3.73	6.33	6.84	5.00	8.01	6.82	7.87	7.47	11.3
caput humerale	25.4	22.6	21.8	62.8	51.1	44.8	79.1	46.7	71.7	84.0	111	134	190	133	89,9	196	200	261
Scrap	0.51	1.31	1.15	1.51	0.19	0.99	4.60	0	1.52	0.29	0	0.73	6,50	1.88	4.56	7.33	2.66	6.38
8. Extrinsic																		
Trapezius pars cervicalis et thoracis	33.1	25.4	26.9	95.6	73.0	57.9	90.7	75.0	98.5	145	184	265	379	183	218	412	449	508
Brachiocephalicus	56.1	43.6	47.3	136	97.7	67.0	140	130	154	166	238	291	452	255	298	450	559	733
Omotransversarius	21.9	10.8	13.5	44.6	40.1	29.6	37.8	30.4	45.5	55.0	62.6	99.1	170	80.1	91.6	151	189	246
Rhomboideus cervicis et thoracis	39.9	38.1	40.7	95.3	74.2	64.3	95.0	81.6	113	154	199	210	417	213	255	339	344	579
Latissimus dorsi	56.1	49.4	52.3	188	153	102	182	169	203	266	359	496	690	389	504	695	876	1047
Serratus ventralis cervicis et thoracis	125	108	102	364	285	232	471	372	482	711	874	1070	1736	1008	1203	1791	2238	2595
Pectoralis profundus	133	98.4	100	330	262	212	349	296	408	495	579	771	1113	640	744	1145	1447	1607
Pectoralis superficialis	44.7	38.6	41.0	112	91.1	58.1	126	136	127	165	204	254	375	220	286	439	620	703
9. Intrinsic (neck)																		
Sternomandibularis	16.4	15.4	16.0	41.2	25.8	22.4	39.3	37.7	35.8	48.6	53.6	68.8	107	71,5	93.1	126	168	167
Sternomastoideus	19.0	22.0	21.4	43.1	40.9	14.8	49.3	47.4	46.5	69.2	118	157	209	94,1	140	193	220	236
Sternothyrohyoideus	5.78	5.76	6.44	20.1	9.44	8.31	30.1	35.6	38.9	31.7	52.7	51.4	43.0	36.6	66.3	48.4	69.8	83.3
Omohyoideus	0.88	0.73	0.59	2.16	0.60	1.01	6.05	14.1	3.03	1.30	3.43	4.46	3.00	4.92	4.90	14.5	16.3	28.6
Splenius capitis et cervicis	22.8	20.0	17.4	48.8	37.3	26.8	54.3	43.2	53.9	68.1	103	117	216	86.0	116	174	235	276
Longissimus cervicis	18.4	13.6	15.9	36.7	29.0	33.6	48.2	37.4	35.1	64.5	84.5	106	165	80.8	98.3	173	229	343
Longissimus capitis	11.6	10.1	8.77	21.8	15.9	17.3	27.0	23.9	23.9	44.3	44.4	50.5	69.0	55.6	55.3	77.9	113	117
Longissimus atlantis	2.53	2.61	2.17	3.09	5.08	1.60	3.39	10.5	4.12	6.91	15.0	4.95	23.5	15,1	15.3	11.8	26.7	11.3
Semispinalis capitis, cervicis et thoracis	74.4	60.8	57.6	149	116	116	187	173	192	260	357	370	651	400	457	590	860	964
Scalenus doralis	7.67	3.96	7.98	22.6	11.4	13.6	23.6	23.1	22.3	36.4	32.3	30.6	39.0	32.9	40,3	63.1	86.1	160
Scalenus ventralis	14.8	16.6	17.7	41.6	29.3	33.6	43.9	42.3	44.0	58.6	90.7	127	174	85,4	117	171	202	248
Intertransversarii cervicis	16.0	20.2	10.6	60.4	56.1	44.4	53.2	50.6	90.8	55.5	106	98.8	203	122	175	215	287	395
Intertransversarii longus	12.8	11.7	11.2	17.7	14.6	14.6	24.6	23.8	25.6	43.6	56.0	72.6	135	78.5	72.1	108	171	160
Longus capitis	11.8	11.3	7.48	28.9	14.8	16.5	34.6	23.5	18.2	42.0	29.1	65.9	103	55,1	78.6	85.9	86,2	81.7
Longus colli	29.1	21.8	20.3	74.7	53.0	49.6	83.0	62.9	71.0	135	177	197	391	235	230	320	405	463
Obliquus capitis caudalis	16.9	14.3	13.2	41.0	31.4	27.2	46.2	42.5	49.1	74.6	71.6	89.2	137	103	106	174	223	208
Obliquus capitis cranialis	7.09	7.66	6.50	18.1	11.0	11.8	18.3	15.7	15.9	21.3	21.3	24.4	81.0	31,0	32.5	35.9	51,1	47.5
Rectus capitis dorsalis major	7.03	6.05	6.27	10.6	11.2	12.2	17.4	16.8	20.0	25.4	31.9	39.1	63.0	37,2	43.1	51.8	80.0	68.7
Rectus capitis dorsalis minor	2.17	1.30	2.23	5.43	2.31	1.17	2.48	4.80	2.29	3.61	6.93	5.06	4.00	6,38	4,52	9.78	23,1	8,18
Rectus capitis ventralis	1.51	1.23	2.05	5.09	3.98	3.77	4.73	4.10	3.66	11.7	11.6	11.5	28.0	14,4	27.8	12.2	35.4	33.1
Rectus capitis lateralis	5.34	5.25	5.04	10.6	9.97	9.23	16.0	12.6	16.3	19.7	22 3	21.2	18.0	19.0	68.8	25.2	39.6	41.3
Multifidis cervicis	23.7	12.6	14.2	40.4	26.2	25.3	29.2	32.8	37.2	37.7	62.7	32.3	100	81.3	88.4	129	183	180
Scrap	37.6	23.0	41.9	43.6	51.8	56.7	142	116	108	178	193	204	348	161	305	393	410	544

APPENDIX 5: FEMALE JERSEY CATTLE CARCASS DISSECTION DATA (g)

IDENTIFICATION No.	2	3	4	5	6	7	8	9	10	17	12	18	1	16	11	13	15	14
10 Thoracic																		
Interspinales	12.3	8.07	6.95	24.9	21.6	22.6	34.6	28.0	33.2	43.0	40.2	56.4	71.5	44.7	54.1	97.1	92.6	93.6
Rectus thoracis	4.95	3.33	3.80	12.2	8.43	8.03	11.4	11.3	13.4	17.2	23.0	34.8	56.5	19.8	29.9	53.4	53.7	105
Serratus dorsalis cranialis	3.27	3.35	3.40	4.29	4.28	6.59	8.61	4.21	5.87	8.63	17.1	22.6	26.0	18.7	14.0	35.1	34.8	64.5
Serratus dorsalis caudalis	2.00	3.10	3.32	13.1	6.05	7.99	11.1	10.7	11.3	18.6	17.5	36.7	50.0	21.4	20.1	58.1	58.7	85.5
Retractor costae	2.39	2.95	2.47	6.58	4.59	1.36	2.45	7.30	5.42	8.31	15.0	20.8	38.0	12.4	24.5	34.8	40.0	49.2
Intercostales	152	109	125	279	213	176	358	289	388	429	525	642	1298	665	750	1254	1628	1828
Transversus thoracis	9.26	5.16	8.22	17.0	14.8	12.3	18.8	212	32.5	24.7	42.8	57.1	95.0	57.7	52.0	116	131	136
Diaphragma	46.1	36.4	31.5	110	80.4	73.8	137	148	165	190	239	304	474	322	349	514	748	864
Scrap	4.22	3.09	3.76	16.6	20.6	18.7	51.8	42.8	44.4	119	824	201	102	103	130	167	230	195
Muscles of the Jaw																		
Masseter	21.2	20.7	21.8	58.8	52.8	55.7	102	105	121	143	156	188	336	273	238	310	382	416
Digastricus	7.22	5.17	6.82	8.83	6.56	8.07	15.2	16.6	11.3	23.4	22.1	36.4	35.5	30.9	26.1	39.2	40.0	57.9
Temporalis	7.78	7.71	6.51	19.4	14.8	17.6	43.8	42.4	44.1	55.7	73.0	85.4	122	81.4	91.6	131	133	148
Pterygoideus medialis	3.95	3.63	4.90	7.53	6.98	7.96	13.4	17.7	22.3	30.0	30.5	19.2	44.5	39.9	35.5	51.1	56.2	101
Pterygoideus lateralis	5.11	6.52	5.11	12.8	15.8	12.6	23.3	22.7	27.7	14.6	34.7	43.3	76.0	67.1	54.9	72.0	87.4	56.6
Vertebrae (whole)																		
Cervical 1	47.7	40.3	39.1	90.2	74.1	61.8	113	104	116	132	151	188	244	221	172	228	293	314
2	59.2	46.3	45.8	99.3	82.8	79.6	131	122	130	130	168	187	254	220	186	235	286	342
3	40.0	33.1	32.1	71.9	56.9	52.0	92.4	84.3	90.8	96.6	129	142	213	161	144	207	247	315
4	42.1	34.7	36.6	75.0	59.9	56.2	97.6	90.8	95.6	105	129	150	234	171	155	206	255	339
5	41.1	35.3	35.0	74.8	63.8	60.4	100	93.1	95.4	111	140	154	245	170	161	211	252	351
6	44.6	35.0	37.5	81.8	64.5	61.8	108	98.0	104	116	145	162	271	182	186	228	298	390
7	35.1	29.8	34.2	70.4	54.0	50.3	90.4	83.3	81.1	97.7	116	134	212	153	152	185	234	294
Thoracic 1	37.6	29.7	30.0	76.0	53.[illegible]	58.2	104	95.7	97.4	112	140	156	253	190	180	215	278	373
2	33.8	26.4	27.4	69.7	48.4	50.3	96.9	87.8	92.1	109	131	146	247	173	173	206	250	324
3	29.7	25.1	25.6	64.3	44.7	44.7	89.5	82.4	87.5	106	128	140	238	159	172	196	231	302
4	27.5	22.3	23.5	58.6	41.7	41.9	85.2	77.5	85.2	100	123	135	228	155	165	191	219	286
5	25.7	21.1	22.3	58.0	39.8	38.6	78.8	75.4	82.1	95.6	123	132	216	147	157	190	208	280
6	24.0	18.6	21.5	53.6	34.8	36.3	73.6	69.4	77.6	87.4	111	124	195	134	146	174	195	259
7	22.2	17.9	19.4	46.2	33.9	32.6	65.5	61.2	68.2	76.0	96.8	111	171	122	124	150	168	224
8	21.5	16.8	17.6	43.7	31.9	30.6	60.6	59.1	62.6	67.9	90.5	101	150	107	108	129	149	203
9	21.1	16.3	17.6	40.6	30.0	30.9	53.9	55.2	58.8	61.7	83.3	95.3	139	97.1	99.3	118	135	186
10	20.1	15.8	16.9	39.5	28.6	28.8	51.1	53.1	56.0	57.8	78.3	87.3	125	91.8	90.4	107	124	167
11	19.6	15.5	17.6	37.6	29.1	29.8	52.6	56.1	56.1	57.3	78.4	87.0	125	93.7	84.2	108	124	157
12	19.9	16.6	18.2	44.8	32.0	30.1	57.6	57.1	61.5	66.2	84.7	89.6	133	108	107	115	141	181
13	22.9	18.1	19.6	48.3	33.8	34.9	63.5	61.4	65.1	69.1	90.1	98.0	154	113	105	129	156	202
Lumbar 1	26.2	21.0	23.6	48.6	37.2	38.7	75.1	69.4	75.5	78.0	107	114	174	135	124	156	184	230
2	29.0	22.6	25.7	56.9	41.5	45.3	82.9	76.8	83.0	85.7	118	131	210	157	144	180	217	262
3	30.5	24.0	25.8	60.9	45.0	48.6	90.9	81.1	88.8	92.3	132	139	213	177	152	191	229	281
4	29.9	24.8	26.5	62.5	46.1	48.6	91.7	82.2	92.6	99.0	136	141	224	181	160	202	241	288
5	30.2	24.3	25.3	63.2	45.8	49.2	95.3	84.5	96.1	98.5	134	149	238	174	163	206	243	298
6	30.6	24.2	24.8	62.0	45.5	47.8	90.5	84.1	96.9	93.4	127	151	231	172	166	214	246	317
Caudal 1	7.03	4.33	5.04	12.6	9.90	7.68	13.7	16.4	20.4	18.9	33.3	30.3	43.5	33.3	30.8	45.2	48.5	72.8
2	6.63	3.48	4.12	11.3	9.39	7.37	13.3	15.8	14.7	18.6	31.3	28.2	43.0	33.3	30.5	43.2	47.8	66.1
Sternum & costal cartilage	148	124	131	422	305	251	533	471	564	687	706	883	1483	1151	1028	1278	1710	2049
Total Rib	178	157	160	447	321	324	649	584	680	795	908	1129	1828	1221	1464	1804	2203	2856

APPENDIX 5: FEMALE JERSEY CATTLE CARCASS DISSECTION DATA (g)

Identification No:	2	3	4	5	6	7	8	9	10	17	12	18	1	16	11	13	15	14
Rib 1	15.4	12.9	13.2	33.0	26.7	29.5	48.4	38.9	42.3	49.8	60.6	63.5	103	81.8	84.8	103	131	161
2	11.2	8.47	9.61	25.9	19.6	20.5	38.0	29.7	33.6	39.1	43.5	50.4	83.0	58.8	66.1	74.5	89.1	105
3	11.5	10.3	9.95	28.7	20.8	21.9	41.9	32.4	39.1	47.5	54.3	55.0	100	68.5	79.1	89.6	100	125
4	12.9	11.7	11.4	29.2	23.3	23.7	45.6	37.6	41.0	53.1	62.2	70.5	102	77.7	90.9	101	114	145
5	14.3	13.6	13.6	35.1	27.0	28.4	53.6	43.0	50.0	65.3	71.2	84.3	125	90.5	108	133	143	182
6	17.0	15.9	15.4	39.0	27.6	30.3	59.8	49.5	62.0	75.3	85.2	106	155	106	130	167	192	250
7	18.3	14.1	15.3	46.7	30.1	32.5	65.5	58.9	69.3	82.3	99.3	113	175	129	148	186	222	296
8	16.8	14.5	15.8	43.2	27.5	28.9	63.8	59.7	71.5	81.3	92.6	114	180	116	158	187	236	290
9	15.5	11.8	13.6	43.0	27.2	25.8	58.7	54.5	63.2	75.7	84.5	118	156	108	130	185	227	274
10	13.1	9.95	10.9	31.0	21.6	21.2	45.0	45.5	55.7	65.1	68.8	93.5	137	97.2	126	151	204	254
11	10.5	9.54	8.63	27.8	16.9	17.2	36.8	34.8	41.6	49.1	60.9	76.8	102	83.8	109	128	165	209
12	9.40	7.87	8.41	21.4	13.5	15.0	30.6	32.4	33.5	40.7	51.3	68.4	83.0	81.2	104	123	150	236
13	5.80	5.61	5.34	14.3	11.5	9.71	24.0	22.0	23.2	34.1	35.0	55.9	60.0	54.5	68.2	102	117	209
Mandible	166	140	154	312	246	275	459	436	492	596	561	740	1191	1051	994	1226	1426	1482
Scapula	72.6	55.1	58.4	156	99.6	108	216	195	207	250	302	408	588	391	421	580	612	819
Humerus	147	115	127	317	231	237	405	385	398	493	510	630	896	679	703	874	932	1101
Radius and ulna	136	100	108	243	185	191	309	288	307	362	399	479	655	516	503	651	655	765
Carpal bones	29.6	21.2	26.5	57.4	43.3	41.3	67.0	67.2	63.5	71.4	72.4	95.1	108	98.8	91.8	104	110	139
Metacarpus	84.2	61.1	66.3	128	99.6	107	156	148	148	169	185	238	277	234	208	248	257	311
Os coxae and sacrum	279	231	242	703	498	503	982	904	1096	1155	1467	1780	2854	2087	1980	2697	2860	3905
Femur	221	181	190	460	352	365	558	513	557	648	707	874	1235	896	886	1049	1153	1416
Patella	12.8	10.9	12.8	23.6	19.6	21.9	33.9	30.8	31.6	37.8	40.0	48.8	71.0	53.5	44.5	60.2	67.9	91.7
Tibia (+ fibula)	166	126	142	305	234	256	354	336	369	425	482	582	769	592	567	696	731	906
Talus	38.0	31.5	33.3	61.0	51.6	55.0	62.5	62.7	63.3	58.7	68.1	89.8	90.0	74.9	72.6	84.7	92.2	105
Calcaneus	39.9	29.1	30.9	61.5	47.5	51.3	71.3	65.8	69.5	75.0	85.0	120	130	104	97.1	124	139	157
Distal tarsus	24.9	18.6	20.3	38.0	33.4	31.9	46.6	39.8	46.4	49.6	51.9	68.2	68.5	59.6	54.2	69.6	78.8	99.2
Metatarsus	94.1	65.9	76.6	145	114	119	172	177	178	189	212	275	304	258	240	285	288	357
Total subcutaneous	5.86	13.4	3.23	105	34.4	4.51	90.2	58.0	66.3	776	1065	1383	1846	400	541	2012	3085	4646
" intermuscular	28.1	73.1	20.6	412	208	22.2	381	324	410	1878	2450	2634	3519	2074	2449	5376	5981	8570
" perirenal fat	21.3	46.5	14.0	124	102	9.02	114	131	133	804	1784	964	2686	1008	726	2328	4769	4646
" channel fat	8.01	17.1	2.23	103	59.0	3.77	36.1	95.0	46.1	129	296	271	594	225	287	672	864	1091
Udder fat	38.8	50.0	34.8	227	212	22.7	246	220	345	886	1000	878	2093	839	963	1149	1287	2030
Cavity fat	0.68	15.2	0.88	6.86	6.04	0.12	6.00	39.2	20.6	154	174	148	720	223	141	631	1027	830
Sternal fat	7.74	3.25	3.00	51.4	23.6	11.9	18.6	28.6	43.5	115	155	160	417	141	126	317	300	379
Fat on Bone	25.3	43.2	21.0	190	120	33.9	218	189	234	540	556	631	408	612	715	946	950	1215
Spinal cord fat	1.61	10.2	2.34	28.2	17.6	5.53	47.4	30.3	28.3	48.8	46.1	41.1	57.3	61.7	42.5	64.7	59.4	55.6
FQ subcutaneous fat	0	0	1.00	39.0	9.72	0	21.4	9.18	15.0	309	444	553	847	128	177	778	1253	1933
FQ intermuscular fat	13.7	40.2	8.68	220	87.8	14.6	195	190	218	1169	1509	1552	2344	1187	1560	3396	3738	5541
FQ fat on bone	9.66	14.3	6.13	103	64.7	9.95	124	108	125	370	344	414	176	373	465	617	598	830
FQ spinal cord fat	1.00	7.39	0.96	16.4	10.4	3.05	29.9	16.8	16.3	25.7	27.9	23.7	31.0	36.8	25.2	35.3	34.9	33.5
HQ subcutaneous fat	5.86	13.4	2.23	66.4	24.7	4.51	68.8	48.8	51.3	466	620	830	999	271	363	1234	1832	2712
HQ intermuscular fat	14.3	32.9	12.0	192	121	7.59	186	134	191	709	941	1081	1175	887	888	1980	2242	3029
HQ fat on bone	15.7	28.9	14.8	86.5	55.7	24.0	93.5	80.7	109	169	212	216	232	239	249	328	351	384
HQ spinal cord fat	0.61	2.78	1.39	11.7	7.23	2.48	17.4	13.5	12.0	23.1	18.1	17.3	26.3	24.9	17.3	29.4	24.5	22.1
FQ Subcutaneous Fat																		
1. Trapezius	0	0	0	0.21	0	0	0	0	0.53	21.8	37.6	53.6	95.0	12.3	12.1	71.2	121	307
2. Thoracic limb	0	0	0	2.22	0.48	0	1.51	0.42	1.11	42.7	22.9	56.4	125	16.1	29.5	100	145	369
3. Latissimus dorsi	0	0	0	4.65	0	0	0.40	0.39	0.73	45.2	103	169	260	20.9	28.6	193	308	556
4. Cutaneus trunci - abdominal	0	0	0	6.47	0.60	0	0	0	3.24	69.6	62.5	72.0	150	17.2	47.0	119	218	402
5. Pectoral	0	0	0	16.9	8.64	0	16.7	8.37	9.29	68.8	116	121	145	46.9	49.2	200	350	232
6. Neck	0	0	0	8.55	0	0	2.83	0	0.13	61.0	102	80.4	71.5	14.8	10.9	94.1	108	66.3

APPENDIX 5: FEMALE JERSEY CATTLE CARCASS DISSECTION DATA (g)

Identification No.	2	3	4	5	6	7	8	9	10	17	12	18	1	16	11	13	15	14
HQ Subcutaneous Fat																		
I Cutaneus trunci-tensor fasciae latae	4.86	8.62	1.23	26.5	11.6	3.51	30.8	29.3	29.5	189	248	287	460	109	165	398	602	763
II Medial aspect of pelvic limb	1.00	3.54	1.00	18.6	9.94	1.00	26.6	14.4	14.8	118	144	202	113	78.2	93.3	258	251	387
III Lateral aspect of pelvic limb	0	0	0	4.71	0	0	1.12	0	0.91	44.1	70.9	101	126	21.2	23.4	188	422	561
IV Abdominal	0	0	0	8.19	0.68	0	2.88	0	0	64.6	77.1	150	157	29.0	39.5	193	301	497
V Longissimus	0	0	0	0	0	0	0	0	0	17.7	24.8	16.8	62.0	3.11	3.46	55.5	107	267
VI Perianal	0	1.22	0	8.43	2.55	0	7.38	5.10	5.79	32.3	55.2	73.6	81.0	30.9	38.6	139	148	237
FQ + HQ Intermuscular Fat																		
1. Axial muscles	2.07	8.34	1.02	64.4	23.1	2.29	67.2	43.2	51.5	299	496	551	613	475	618	1220	1126	2160
2. Extrinsic muscles	3.57	16.0	4.97	83.2	32.3	5.46	50.0	63.7	70.3	506	575	513	900	258	434	1069	1415	1636
3. Intercostal	1.00	4.29	1.00	17.9	14.9	2.12	25.2	39.7	38.1	115	152	172	301	192	224	444	491	673
4. Abdominal	1.14	5.34	0.29	51.2	15.2	0.46	30.9	8.73	31.9	258	358	403	450	306	297	843	1349	1756
5. Sublumbar	1.92	5.48	1.52	26.7	19.4	0.10	24.9	23.8	21.7	82.6	142	207	105	123	113	254	233	329
6. Proximal thoracic limb	5.85	7.31	2.00	25.8	13.4	3.06	33.8	41.9	37.2	139	124	180	320	123	190	381	288	404
7. Distal thoracic limb	1.38	2.15	0.40	6.03	3.08	1.71	4.45	5.33	14.2	18.3	21.9	22.1	72.0	20.6	23.3	24.4	27.8	40.3
8. Proximal pelvic limb	7.25	19.8	8.05	105	68.7	6.50	114	81.7	111	355	428	466	630	477	495	912	833	1252
9. Distal pelvic limb	4.87	4.25	2.40	31.6	18.0	0.63	30.6	16.3	33.5	103	152	117	128	96.5	53.9	228	216	320
FQ + HQ Bone Fat																		
1. Cervical, thoracic, lumbar	1.99	5.77	0	40.1	33.6	6.95	36.1	44.2	50.6	135	184	198	113	172	263	280	287	385
2. Sternum + rib	1.37	5.25	0	49.5	24.6	3.00	69.1	45.2	61.9	227	170	253	100	200	219	352	355	556
3. FQ long bones	6.29	5.22	6.13	23.1	16.6	0	31.4	27.4	30.9	44.5	43.6	34.2	63.0	58.4	60.0	65.7	62.6	87.4
4. Pelvic girdle + sacrum	0.37	3.66	0	12.3	4.74	0.57	18.5	14.6	29.8	40.2	47.9	66.5	58.0	43.0	46.0	90.7	83.2	76.0
5. HQ long bones	15.3	23.3	14.8	65.4	40.7	23.4	63.1	57.6	61.0	92.7	110	78.2	232	139	126	157	161	110
FQ Fascia, tendon + ligament	144	109	144	302	328	237	434	479	414	665	708	780	830	1121	687	1279	1550	1491
HQ " " "	144	113	152	328	281	251	447	447	431	642	873	907	1067	844	1133	1192	1788	1894
Ligamentum nuchae ($C-T_1$)	22.2	16.8	21.9	42.5	38.6	28.6	49.6	49.5	51.7	65.8	74.5	86.5	118	81.3	87.7	103	115	111
" " (T_1-T_{12})	13.1	10.3	13.4	31.9	25.9	18.4	35.7	38.4	33.3	47.3	67.6	78.2	88.0	61.3	64.4	89.7	112	101
Total " "	35.3	27.2	35.3	74.4	64.5	47.1	85.3	87.9	85.0	113	142	164	206	142	152	193	228	213
Spinal cord	32.3	23.6	32.8	45.3	41.5	41.3	56.6	52.5	63.6	64.1	72.6	68.6	85.0	68.8	85.3	111	127	140
Heart	210	158	187	378	380	280	665	502	697	650	769	779	1663	1397	1561	1639	2005	2431
Lungs	433	262	331	677	568	443	1120	1312	1716	1255	1398	1369	2559	2227	1578	2312	2965	3750
Liver	592	654	472	1504	1199	964	2064	2287	2260	1863	2149	3182	3738	4376	2877	6243	7069	7346
Spleen	78.0	78.5	78.5	209	205	121	219	253	239	307	370	290	438	311	397	534	693	817
Left Kidney	49.2	61.9	45.3	186	127	87.6	172	201	168	151	180	270	285	296	304	363	568	653
Right Kidney	49.0	63.4	51.9	174	126	91.5	163	186	164	164	177	288	268	262	274	443	546	707
Stomach	416	545	372	1144	860	1415	4100	4495	4343	4910	7215	9200	10300	10650	10900	15000	26150	35650
Intestine	1146	1255	941	3462	3208	2682	6900	6246	6253	8572	8617	10100	14300	12100	12600	15193	22000	31800
Uterus	6.64	7.00	7.69	27.3	18.3	13.0	21.0	23.0	30.0	100	207	93.0	180	150	170	4372	4835	4000
Left Ovary	0.35	0.74	0.29	2.87	1.48	1.04	1.40	3.00	3.00	4.00	5.68	4.00	2.20	2.20	3.19	9.06	16.0	16.0
Right ovary	0.30	1.25	0.18	1.71	0.89	1.31	0.90	1.00	3.00	4.00	2.15	5.00	5.80	5.80	4.45	2.55	12.0	12.0
Coccygeus	1.34	1.31	1.32	4.92	5.03	2.95	7.30	9.24	8.22	7.21	9.47	12.9	40	6.37	13.4	30.4	28.2	34.0
Levator ani	2.05	1.89	1.03	3.24	3.25	3.90	4.66	2.44	8.09	11.4	15.2	13.7	24	17.1	27.4	37.9	29.9	52.0

APPENDIX 5: FEMALE JERSEY CATTLE CARCASS DISSECTION DATA (mm)

Identification No.	2	3	4	5	6	7	8	9	10	17	12	18	1	16	11	13	15	14
LINEAR MEASUREMENTS																		
1. Crown-rump	680	655	700	890	780	850	1075	1090	1050	1225	1310	1280	1600	1420	1470	1550	1610	1750
2. Minimum neck girth	370	360	300	412	505	465	510	495	500	610	640	665	655	685	630	760	790	820
3. Height at withers	700	600	640	790	760	785	1000	920	980	990	1010	1110	1120	1180	1110	1190	1210	1340
4. Width between tuber coxae	170	175	170	270	212	225	315	265	290	350	400	380	310	430	410	480	538	580
5. Width between tuber ischii	32	32	48	75	65	62	90	60	75	100	100	130	170	120	120	145	160	180
Length of cervical vertebrae	208	192	215	260	249	243	310	292	297	345	344	372	395	379	370	395	427	510
" " thoracic "	299	291	287	403	374	371	474	461	468	503	547	553	669	602	599	662	716	748
" " lumbar "	150	142	144	205	186	187	240	240	243	265	282	285	348	325	325	352	375	385
" " sacrum "	83	94.2	99	145	129	124	164	167	208	185	205	202	240	220	219	231	247	245
Total length	740	720	745	1014	938	925	1187	1160	1216	1298	1378	1412	1652	1526	1513	1640	1765	1888
Length of caudal vertebrae	44.4	38.1	39.0	56.1	52.4	50.7	65.2	66.0	62.8	73.3	83.5	79.8	101	94.0	100	96.6	105	102
Length of rib 1	112	111	115	140	142	151	185	173	173	197	200	121	243	239	231	271	285	280
" " " 2	185	177	180	239	210	220	280	265	271	308	291	334	417	392	363	423	462	488
Scapula: length	189	175	179	241	210	222	270	268	282	295	304	329	373	353	355	395	407	418
width (distal neck)	21.7	19.5	20.6	26.5	21.6	25.7	30.0	28.0	29.4	35.6	37.1	40.4	47.0	45.0	41.9	48.6	53.2	58.9
width (proximal)	89.0	80.8	83.0	115	99.5	105	131	120	128	138	142	159	220	159	161	176	174	197
Humerus: length	154	146	152	192	182	177	217	206	215	228	227	235	280	266	233	285	286	285
width: deltoid crest	67.5	62.8	66.6	89.1	80.8	75.4	91.6	92.9	92.4	101	99.0	105	125	120	259	130	137	141
width: mid-shaft	16.5	15.0	15.0	20.8	20.6	20.0	23.3	21.3	22.9	23.7	25.5	29.6	37.0	29.4	28.9	33.3	34.9	39.0
width: proximal	18.5	54.2	55.6	75.2	68.6	68.4	85.1	81.6	82.3	91.9	92.5	97.7	115	105	120	108	114	113
width: distal	49.6	46.8	47.4	63.4	59.1	59.2	66.3	61.5	64.8	65.1	65.6	71.2	72.0	69.8	67.0	68.9	72.0	72.8
Ulna: length	191	173	186	232	222	218	265	253	263	283	278	296	338	315	308	340	341	349
width	10.2	9.30	10.0	11.5	11.5	12.0	12.9	10.6	12.4	13.2	15.2	16.0	13.0	17.7	14.7	17.0	18.3	15.8
Radius: length	155	142	155	188	177	176	212	202	211	218	220	227	253	251	245	268	259	268
width	12.4	10.2	10.6	13.5	12.1	12.7	15	14.5	14.8	15.2	17.2	18.2	22.2	19.2	18.8	24.9	22.2	22.8
Metacarpus: length	151	133	143	169	160	157	179	175	180	172	179	191	196	196	183	194	191	199
width	13.6	11.7	12.7	15.9	14.4	15.3	16.5	16.3	16.0	17.1	17.7	21.0	22.0	19.8	19.0	20.9	21.7	22.5
Mandible: length	183	173	175	228	208	210	244	242	247	272	261	294	333	321	322	349	352	358
height	93.8	86.1	89.8	118	115	112	140	138	150	169	162	169	203	203	200	201	220	215
Os coxae: betw. tuber ischii	36.4	32.7	42.7	72.9	64.0	62.3	85.0	68.9	72.0	84.0	95.2	112	186	130	124	150	136	146
betw. tuber coxae	134	124	136	193	172	187	245	235	247	278	291	315	385	354	350	404	454	480
conjugate diameter	77.4	72.3	74.6	102	100	92.2	120	119	137	137	146	145	195	164	161	195	207	227
transverse "	50.8	49.6	54.8	82.3	72.8	71.6	94.4	92.4	103	97.2	119	114	143	142	138	143	167	157
vertical "	68.4	53.6	57.1	75.2	69.6	68.5	91.1	89.3	90.3	97.6	101	121	173	144	135	175	177	194
Femur: length	189	174	186	240	225	222	269	258	264	286	297	310	371	334	334	342	360	372
width	16.6	15.8	15.3	20.2	19.3	19.1	23.2	21.8	23.0	27.0	26.2	31.0	30.7	27.6	29.0	33.5	33.8	37.3
Tibia: length	196	172	192	238	227	222	265	256	266	277	278	294	340	317	305	330	340	343
width	15.1	13.6	15.2	18.9	12.2	17.3	18.5	17.6	18.6	18.8	21.8	22.3	30.0	23.7	23.8	25.6	24.2	28.2
Metatarsus: length	168	149	162	186	181	176	206	202	204	196	201	214	218	225	209	219	217	231
width	14.8	12.0	13.2	17.7	15.2	16.5	18.5	18.4	18.6	19.0	20.4	24.2	23.7	21.7	22.4	25.0	23.3	25.5

REFERENCES

Allden, W. G. (1970). The effects of nutritional deprivation on the subsequent productivity of sheep and cattle. Nutrition Abstracts and Reviews 40, 1167-1184.

Allen, C. E. (1976). Cellularity of adipose tissue in meat animals. Federation Proceedings 35, 2302-2307.

Allen, C. E., Beitz, D. C., Cramer, D. A. and Kauffman, R. G. (1976). Biology of fat in meat animals. North Central Regional Research Publication No. 234. College of Agriculture and Life Sciences, University of Wisconsin, Madison.

Anderson, D. B. (1972). The cellular development of adipose tissue. Proceedings of the 25th Annual Reciprocal Meat Conference pp. 9-38.

Atkinson, T., Fowler, V. R., Garton, G. A. and Lough, A. K. (1972). A rapid method for the accurate determination of lipid in animal tissues. Analyst 97, 562-568.

Barr, D. R. (1969). Using confidence intervals to test hypotheses. Journal of Quality Technology 1, 256-258.

Bell, E. T. (1909). II. On the histogenesis of adipose tissue of the ox. American Journal of Anatomy 9, 412-438.

Bellows, R. A., Gibson, R. B., Anderson, D. C. and Short, R. E. (1971a). Precalving body size and pelvic area relationships in Hereford heifers. Journal of Animal Science 33, 455-457.

Bellows, R. A., Short, R. E., Anderson, D. C., Knapp, B. W. and Pahnish, O. F. (1971b). Cause and effect relationships associated with calving difficulty and calf birth weight. Journal of Animal Science 33,407-415.

Bendall, J. R. and Voyle, C. A. (1967). A study of the histological changes in the growing muscles of beef animals. Journal of Food Technology 2, 259-283.

Berg, R. T., Andersen, B. B. and Liboriussen, T. (1978a). Growth of bovine tissues. 1. Genetic influences on growth patterns of muscle, fat and bone in young bulls. Animal Production 26, 245-258.

Berg, R. T., Andersen, B. B. and Liboriussen, T. (1978b). Growth of bovine tissues. 2. Genetic influences on muscle growth and distribution in young bulls. Animal Production 27, 51-61.

Berg, R. T., Andersen, B. B. and Liboriussen, T. (1978c). Growth of bovine tissues. 3. Genetic influences on patterns of fat growth and distribution in young bulls. Animal Production 27, 63-69.

Berg, R. T., Andersen, B. B. and Liboriussen, T. (1978d). Growth of bovine tissues. 4. Genetic influences on patterns of bone growth and distribution in young bulls. Animal Production 27, 71-77.

Berg, R. T. and Butterfield, R. M. (1966). Muscle:bone ratio and fat percentage as measures of beef carcass composition. Animal Production 8, 1-11.

Berg, R. T. and Butterfield, R. M. (1968). Growth patterns of bovine muscle, fat and bone. Journal of Animal Science 27, 611-619.

Berg, R. T. and Butterfield, R. M. (1976). New Concepts of Cattle Growth. Sydney University Press, Press Building, University of Sydney.

Berg, R. T., Jones, S. D. M., Price, M. A., Fukuhara, R., Butterfield, R. M. and Hardin, R. T. (1979). Patterns of carcass fat deposition in heifers, steers and bulls. Canadian Journal of Animal Science 59, 359-366.

Berg, R. T. and Mukhoty, H. M. (1970). Lean distribution in carcasses from bulls, steers and heifers of various breeds. 49th Annual Feeders' Day Report, Department of Animal Science, the University of Alberta, Edmonton. pp. 40-41.

Bergström, P. L. (1978). Sources of variation in muscle weight distribution. In Patterns of Growth and Development in Cattle vol. 2, pp. 91-131 (ed. H. De Boer and J. Martin) Current Topics in Veterinary Medicine. Martinus Nijhoff - The Hague.

Bertalanffy, L. von (1960). Principles and theory of growth. In Fundamental aspects of normal and malignant growth pp. 137-259 (ed. W. W. Nowinski) Elsevier, Amsterdam.

Black, J. L. (1974). Manipulation of body composition through nutrition. Proceedings of the Australian Society of Animal Production 10, 211-218.

Brady, D. E. (1937). A study of the factors influencing tenderness and texture of beef. 30th Annual Meeting of the American Society of Animal Production pp. 246-250.

Brännäng, E. (1966). Studies on monozygous cattle twins. XVIII. The effect of castration and age of castration on the growth rate, feed conversion and carcass traits of Swedish Red and White cattle. Part I Lantbrukshögskolans Annaler 32, 329-415.

Brännäng, E. (1971). Studies on monozygous cattle twins. XXIII. The effect of castration and age of castration on the development of single muscles, bones and special sex characters. Part II Swedish Journal of Agricultural Research 1, 69-78.

Broad, T. E., Davies, A. S. and Tan, G. Y. (1980). Pre- and postnatal study of the carcass growth of the sheep. 2. The cellular growth of adipose tissues. Animal Production 31, 73-79.

Broadbent, P. J., Ball, c. and Dodsworth, T. L. (1976). Growth and carcass characteristics of purebred and crossbred cattle with special reference to their carcass lean:bone ratios. Animal Production 23, 341-348.

Brody, S. (1945). Linear growth, form and function. In Bioenergetics and Growth Chapter 17, pp. 575-663. Reinhold, New York.

Brook, C. G. D. (1978). Cellular growth : Adipose tissue. In Human Growth. 2. Postnatal Growth Chapter 2, pp. 21-33. (ed. F. Falkner and J. M. Tanner) Plenum Press, New York.

Bulfer, J. M. and Allen, C. E. (1979). Fat cells and obesity. Bioscience 29, 736-741.

Butterfield, R. M. (1964a). Estimation of carcass composition: the anatomical approach. In Carcase Composition and Appraisal of Meat Animals, Technical Conference, University of Melbourne, 1963, pp. 4-1 to 4-13 (ed. D. E. Tribe). East Melbourne: CSIRO.

Butterfield, R. M. (1964b). Relative growth of the musculature of the ox. In Carcase Composition and Appraisal of Meat Animals, Technical Conference, University of Melbourne, 1963, pp. 7-1 to 7-20 (ed. D. E. Tribe). East Melbourne: CSIRO.

Butterfield, R. M. and Berg, R. T. (1966a). A classification of bovine muscles, based on their relative growth patterns. Research in Veterinary Science 7, 326-332.

Butterfield, R. M. and Berg, R. T. (1966b). Relative growth patterns of commercially important muscle groups of cattle. Research in Veterinary Science 7, 389-393.

Butterfield, R. M. an May, N. D. S. (1966). Muscles of the ox. University of Queensland Press, St. Lucia, Brisbane, Queensland.

Callow, E. H. (1948). Comparative studies of meat. II. The changes in the carcass during growth and fattening, and their relation to the chemical composition of the fatty and muscular tissues. Journal of Agricultural Science, Cambridge 38, 174-199.

Callow, E. H. (1962). Comparitive studies of meat. VIII. The percentage of fat in the fatty and muscular tissues of steers and the iodine number of the extracted fat, as affected by breed and level of nutrition. Journal of Agricultural Science, Cambridge 58, 295-307.

Carroll, F. D., Clegg, M. T. and Kroger, D. (1964). Carcass characteristics of Holstein and Hereford steers. Journal of Agricultural Science, Cambridge 62, 1-6.

Cassens, R. G., Cooper, C. C. and Morita, S. (1969). Differentiation of muscle fibers during growth and development. Proceedings of the 22nd Annual Reciprocal Meat Conference. pp. 101-120.

Clark, R. G. and Tarttelin, M. F. (1976). An accurate method for the preparation and analysis of the composition of animal tissue. Physiology and Behaviour 17, 351-352.

Close, R. I. (1972). Dynamic properties of mammalian skeletal muscles. Physiological Reviews 52, 129-197.

Colomer-Rocher, F., Bass, J. J. and Johnson, D. L. (1980). Beef carcass conformation and some relationships with carcass composition and muscle dimensions. Journal of Agricultural Science, Cambridge 94, 697-708.

Cornforth, D. P., Hecker, A. L., Cramer, D. A., Spindler, A. A. and Mathias, M. M. (1980). Maturity and its relationship to muscle characteristics of cattle. Journal of Animal Science 50, 75-80.

Culling, C. F. A. (1974). Handbook of Histopathological and Histochemical techniques. Third edition, Butterworths.

Davies, A. S. (1972). Postnatal changes in the histochemical fibre types of porcine skeletal muscle. Journal of Anatomy 113, 213-240.

Davies, A. S. (1974a). A comparison of tissue development in Pietrain and Large White pigs from birth to 64 kg live weight. 1. Growth changes in carcass composition. Animal production 19, 367-376.

Davies, A. S. (1974b). A comparison of tissue development in Pietrain and Large White pigs from birth to 64 kg live weight. 2. Growth changes in muscle distribution. Animal Production 19, 377-387.

Davies, A. S. (1979). Musculoskeletal growth gradients: A contribution to quadrupedal mechanics. Zentralblatt für Veterinärmedizin C. Anatomie Histologie Embryologie 8, 164-167.

Davies, A. S. and Gunn, H. M. (1972). Histochemical fibre types in the mammalian diaphragm. Journal of Anatomy 112, 41-60.

Davies, A. S. and Kallweit, E. (1979). The effect of body weight and maturity on the carcass composition of the pig. Zeitschrift für Tierzüchtung und Züchtungbiologie 96, 6-17.

Davies, A. S., Pearson, G. and Carr, J. R. (1980). The carcass composition of male, castrated male and female pigs resulting from two levels of feeding. Journal of Agricultural Science, Cambridge (In press).

Davies, A. S. and Pryor, W. J. (1977). Growth changes in the distribution of dissectable and intramuscular fat in pigs. Journal of Agricultural Science, Cambridge 89, 257-266.

De Luca, H. F. and Cohen, P. P. (1964). Suspending media for animal tissues. In Manometric Techniques pp. 131-133. (ed. W. W. Umbreit, R. H. Burris and J. H. Stauffer) Burgess Publishing Co., Minnesota.

Dijkstra, M. (1979). Factoren die invloed hebben op de verdeling van het vetweefsel over verhillende vetdepots in runderkarkassen. (Factors affecting the distribution of fatty tissues between several fat depots in bovine carcass) Rapport B-138 Instituut voor Veeteeltkundig Onderzoek 'Schoonord' Driebergseweg 10D-Zeist (Netherlands).

Elsley, F. W. H., McDonald, I. and Fowler, V. R. (1964). The effect of plane of nutrition on the carcasses of pigs and lambs when variations in fat content are excluded. Animal Production 6, 141-154.

Enser, M. and Wood, J. D. (1978). The development of adipose tissue in cattle. In Patterns of Growth and Development in Cattle, vol. 2, pp. 243-253 (ed. H. De Boer and J. Martin) Current Topics Veterinary Medicine. Martinus Nijhoff - The Hague.

Enser, M. B., Wood, J. D., Restall, D. J. and MacFie, H. J. H. (1976). The cellularity of adipose tissue from pigs of different weights. Journal of Agricultural Science, Cambridge 86, 633-638.

Faulkner, L. C. (1971). Male reproduction. In Veterinary Endocrinology and Reproduction. Chapter 9, pp. 155-205 (ed. L. E. McDonald). Lea and Febiger, Philadelphia.

Fidanza, F., Keys, A. and Anderson, J. T. (1953). Density of body fat in man and other mammals. Journal of Applied Physiology 6, 252-256.

Fourie, P. D., Kirton, A. H. and Jury, K. E. (1970). Growth and development of sheep. II. Effect of breed and sex on the growth and carcass composition of the Southdown and Romney and their cross. New Zealand Journal of Agricultural Research 13, 753-770.

Fowler, V. R., Taylor, A. G. and Livingstone, R. M. (1969). Nutritional implications of differences in tissue growth due to sex. In Meat Production from Entire Male Animals. pp. 51-61. (ed. D. N Rhodes). Churchill, London.

Gaili. E. S. E. (1978). A note on the effect of breed-type and sex on the distribution of intermuscular fat in carcasses of sheep. Animal Production 26, 217-219.

Gauthier, G. F. (1971). The structural and cytochemical heterogeneity of mammalian skeletal muscle fibers. In Contractility of Muscle Cells and Related Processes. pp. 131-150. Symposium of the Society of General Physiologists. (ed. R. J. Podolsky) Englewood Cliffs, New Jersey: Prentice-Hall, Inc.

Getty, R. (1975). Sisson and Grossman's "The Anatomy of the Domestic Animals" Volume 1. Fifth edition. W. B. Saunders Company, Philadelphia.

Goldrick, R. B. (1967). Morphological changes in the adipocyte during fat deposition and mobilization. American Journal of Physiology 212, 777-782.

Goldspink, G. (1972). Postembryonic growth and differentiation of striated muscle. In The Structure and Function of Muscle. Second edition. Volume 1, pp. 179-236 (ed. G. H. Bourne) Academic Press, New York.

Hammond, J. (1932). Growth and the Development of Mutton Qualities in the Sheep. Oliver and Boyd, Edinburgh.

Hankins, O. G., Knapp, B, Jr. and Phillips, R. W. (1943). The muscle-bone ratio as an index of merit in beef and dual-purpose cattle. Journal of Animal Science 2, 42-49.

Hansson, I., Lundström, K. and Malmfors, B. (1975). Effect of sex and weight on growth, feed efficiency and carcass characteristics of pigs. 2. Carcass characteristics of boars, barrows and gilts, slaughtered at four different weights. Swedish Journal of Agricultural Research 5, 69-80.

Haugebak, C. D., Hedrick, H. B. and Asplund, J. M. (1974). Adipose tissue accumulation and cellularity in growing and fattening lambs. Journal of Animal Science 39. 1016-1025.

Hegarty, P. V. J. (1971). Muscle fiber growth and development. Proceedings of the 24th Annual Reciprocal Meat Conference pp. 319-344.

Holloszy, J. O. and Booth, F. W. (1976). Biochemical adaptations to endurance exercise in muscle. Annual Review of Physiology 38, 273 -291.

Holmes, J. H. G. and Ashmore, C. R. (1972). A histochemical study of development of muscle fiber type and size in normal and "double muscled" cattle. Growth 36, 351-372.

Hood, R. L. (1977). Cellularity of adipose tissue during post-natal development. Proceedings of the Nutrition Society of Australia 2, 43-52.

Hood, R. L. and Allen, C. E. (1973). Cellularity of bovine adipose tissue. Journal of Lipid Research 14, 605-610.

Hood, R. L. and Thornton, F. F. (1979). The cellularity of ovine adipose tissue. Australian Journal of Agricultural Research 30, 153- 161.

Hooker, C. W. (1944). The postnatal history of function of the interstitial cells of the testis of the bull. American Journal of Anatomy 74, 1-37.

Huxley, J. S. (1924). Constant differential growth-ratios and their significance. Nature 114, 895-896.

Huxley, J. S. (1932). Problems of Relative Growth. Metheun, London.

Johnson, E. R. and Beattie, A. W. (1973). Variation in muscle fibre diameter among sections and intra-sections and between contralateral muscles in seven bovine muscles. Journal of Agricultural Science, Cambridge 81, 9-14.

Johnson, E. R., Butterfield, R. M. and Pryor, W. J. (1972). Studies of fat distribution in the bovine carcass. I. The partition of fatty tissues between depots. Australian Journal of Agricultural Research 23, 381-388.

Jones, S. D. M., Price, M. A. and Berg, R. T. (1978). Effects of breed and sex on the relative growth and distribution of bone in cattle. Canadian Journal of Animal Science 58, 157-165.

Jones, S. D. M., Price, M. A. and Berg, R. T. (1980). Tissue growth and distribution in bulls and heifers of two breeds. 59th Annual Feeders' Day Report, Agriculture and Forestry Bulletin, University of Alberta, Edmonton. pp. 26-29.

Joubert, D. M. (1956). An analysis of factors influencing post-natal growth and development of the muscle fibre. Journal of Agricultural Science, Cambridge 47, 59-102.

Jury, K. E., Fourie, P. D. and Kirton, A. H. (1977). Growth and development of sheep. IV. Growth of the musculature. New Zealand Journal of Agricultural Research 20, 115-121.

Kempster, A, J., Avis, P. R. D. and Smith, R. J. (1976). Fat distribution in steer carcasses of different breeds and crosses 2. Distribution between joints. Animal Production 23, 223-232.

Kempster, A. J., Cuthbertson, A. and Harrington, G. (1976). Fat distribution in steer carcasses of different breeds and crosses 1. Distribution between depots. Animal Production 23, 25-34.

Kempster, A. J., Cuthbertson, A. and Smith, R. J. (1976). Variation in lean distribution among steer carcasses of different breeds and crosses. Journal of Agricultural Science, Cambridge 87, 533-542.

Kirtland, J. and Gurr, M. T. (1979). Adipose tissue cellularity: a review 2. The relationship between cellularity and obesity. International Journal of Obesity 3,15-55.

Knittle, J. L. (1978). Adipose tissue development in man. In Human Growth. 2. Postnatal Growth Chapter 11, pp. 295-315. (ed. F. Falkner and J. M. Tanner) Plenum Press, New York.

Kochakian, C. D. (1966). Regulation of muscle growth by androgens. In The Physiology and Biochemistry of Muscle as a Food. pp. 81-112 (ed. E. J. Briskey, R. G. Cassens and J. C. Trautman) The University of Wisconsin Press, Madison.

Krotkiewski, M., Sjöström, L., Björntorp, P. and Smith, U. (1975). Regional adipose tissue cellularity in relation to metabolism in young and middle-aged women. Metabolism, Clinical and Experimental 24, 703-710.

Laster, D. B. (1974). Factors affecting pelvic size and dystocia in beef cattle. Journal of Animal Science 38, 496-503.

Lee, Y. B., Kauffman, R. G. and Grummer, R. H. (1973a). Effect of early nutrition on the development of adipose tissue in the pig. I. Age constant basis. Journal of Animal Science 37, 1312-1318.

Lee, Y. B., Kauffman, R. G. and Grummer, R. H. (1973b). Effect of early nutrition on the development of adipose tissue in the pig. I. Weight constant basis. Journal of Animal Science 37, 1319-1325.

Lemonnier, D. (1971). Sex difference in the number of adipose cells from genetically obese rats. Nature (London) 231, 50.

Lemonnier, D. (1972). Effect of age, sex and site on the cellularity of the adipose tissue in mice and rats rendered obese by high-fat diet. Journal of Clinical Investigation 51, 2907-2915.

Lohse, C. L. (1973). The influence of sex on muscle growth in Merino sheep. Growth 37, 177-187.

Lohse, C. L., Moss, F. P. and Butterfield, R. M. (1971). Growth patterns of muscles of Merino sheep from birth to 517 days. Animal Production

13, 117-126.

Lorch, E. and Rentsch, G. (1969). A simple method for staining and counting isolated adipose tissue fat cells. Diabetologia 5, 356-357.

Malina, R. M. (1978). Growth of muscle tissue and muscle mass. In Human Growth. 2. Postnatal Growth. Chapter 10, pp. 273-294 (ed. F. Falkner and J. M. Tanner) Plenum Press, New York.

McClelland, T. H., Bonaiti, B. and Taylor, St. C. S. (1976). Breed differences in body composition of equally mature sheep. Animal Production 23, 281-293.

McDonald, L. E. (1971). Patterns of reproduction. In Veterinary Endocrinology and Reproduction. Chapter 12, pp. 325-350 (ed. L. E. McDonald) Lea and Febiger, Philadelphia.

McMeekan, C. P. (1940). Growth and development in the pig, with special reference to carcass quality characteristics. Journal of Agricultural Science, Cambridge 30, 276-343.

Meat and Livestock Commission (1975). Progress on beef carcass classfication. Marketing and Meat Trade Technical Bulletin No. 22. Meat and Livestock Commission, Bletchley, Bucks.

Medawar, P. B. (1950). A discussion on the measurement of growth and form: Transformation of shape. Proceedings of the Royal Society of London B137, 474-479.

Melichna, J., Gutman, E., Herbrychová, A. and Stichová, J. (1972). Sexual dimorphism in contraction properties and fibre pattern of the flexor carpi radialis muscle of the frog (*Rana temporaria* L.). Experientia 28, 89-91.

Merkel, R. A., Spooner, M. E., Emery, R. S., Romsos, D. R. and Parr, A. F. (1973). Cellularity of ovine subcutaneous adipose-tissue. Journal of Animal Science 37, 268 (Abstract No. 154).

Moody, W. G., Kemp, J.D., Mahyuddin, M., Johnston, D. M. and Ely, D. G. (1980). Effect of feeding systems, slaughter weight and sex on histological properties of lamb carcasses. Journal of Animal Science 50, 249-256.

Moody, W. G., Tichenor, D. A., Kemp, J. D. and Fox, J. D. (1970). Effects of weight, castration and rate of gain on muscle fiber and fat cell diameter in two ovine muscles. Journal of Animal Science 31, 676-680.

Moulton, C. R. (1923). Age and chemical development in mammals. Journal of Biological Chemistry 57, 79-97.

Mukhoty, H. and Berg, R. T. (1971). Influence of breed and sex on the allometric growth patterns of major bovine tissues. Animal Production 13, 219-227.

Mukhoty, H. and Berg, R. T. (1973). Influence of breed and sex on muscle weight distribution of cattle. Journal of Agricultural Science, Cambridge 81, 317-326.

Mukhoty, H. and Berg, R. T. (1974). Influence of breed and sex on growth patterns and linear relationship among major bovine tissues. 1st World Congress on Genetics Applied to Livestock Production. Madrid, Spain. pp. 839-849.

Murray, D. M., Tulloh, N. M. and Winter, W. H. (1974). Effects of three different growth rates on empty body weight, carcass weight and dissected carcass composition of cattle. Journal of Agricultural Science, Cambridge 82, 535-547.

Neville, W. E., Jr., Smith, J. B., Mullinix, B. G., Jr., and McCormick, W. C. (1978). Relationships between pelvic dimensions, between pelvic dimensions and hip height and estimates of heritabilities. Journal of Animal Science 47, 1089-1094.

New Zealand Meat Producers Board (1975). New Zealand export meat grades.

Padykula, H. A. and Herman, E. (1955). The specificity of the histochemical method for adenosine triphosphatase. Journal of Histochemistry and Cytochemistry 3, 170-195.

Peter, J. B. (1971). Histochemical, biochemical and physiological studies of skeletal muscle and its adaptation to exercise. In Contractility of Muscle Cells and Related Processes. pp. 151-173. Symposium of the Society of General Physiologists. (ed. R. J. Podolsky) Englewood Cliffs, New Jersey: Prentice-Hall, Inc.

Preston, T. R. and Willis, M. B. (1974). Intensive Beef Production. Second edition. Pergamon Press, Oxford.

Robelin, J. (1978). Développement différentiel du squelette chez les bovins. Annales de Biologie animale, Biochemie, Biophysique 18, 1-4.

Robertson, D. D. and Baker, D. D. (1933). Histological differences in the muscles of full, half and rough fed steers. Agricltural Experiment Station, Research Bulletin No. 200. College of Agriculture, University of Missouri.

Russel, W. S. (1975). The growth of Ayshire cattle: An analysis of linear body measurements. Animal Production 21, 217-226.

Schön, I. (1978). The development of fat cells in different anatomical positions in carcasses of young bulls, heifers and cow-heifers. In Patterns of Growth and Development in Cattle vol. 2. pp. 255-265 (ed. H. De Boer and J. Martin) Current Topics in Veterinary Medicine. Martinus Nijhoff - The Hague.

Seebeck, R. M. (1967). Developmental growth and body weight loss of cattle. I. Experimental design, body weight growth, and the effects of development growth and body weight loss on the dressed carcass and the offal. Australian Journal of Agricultural Research 18, 1015-1031.

Seebeck, R. M. (1968). Developmental studies of body composition. Animal Breeding Abstracts 26, 167-181.

Seebeck, R. M. (1973a). The effect of body-weight loss on the composition of Brahman cross and Africander cross steers. 1. Empty body weight, dressed carcass weight and offal components. Journal of Agricultural Science, Cambridge 80, 201-210.

Seebeck, R. M. (1973b). The effect of body-weight loss on the composition of Brahman cross and Africander cross steers. II. Dissected components of the dressed carcass. Journal of Agricultural Science, Cambridge 80,411-423.

Seebeck, R. M. and Tulloh, N. M. (1968a). Developmental growth and body weight loss of cattle. II. Dissected components of commercially dressed and jointed carcass. Australian Journal of Agricultural Research 19, 477-495.

Seebeck, R. M. and Tulloh, N. M. (1968b). Developmental growth and body weight loss of cattle. III. Dissected components of the commercially dressed carcass, following anatomical boundaries. Australian Journal of Agricultural Research 19, 673-688.

Sjöström, L., Björntorp, P. and Vråna, J. (1971). Microscopic fat cell size measurements on frozen-cut adioise tissue in comparison with automatic determinations of osmium-fixed fat cells. Journal of Lipid Research 12, 521-530.

Sjöström, L., Smith, U., Krotkiewski, M. and Björntörp, P. (1972). Cellularity in different regions of adipose tissue in young men and women. Metabolism 21, 1143-1153.

Smuts, M. M. S. (1976). Areas of muscular attachment and their correlation with foraminous areas of the cervical vertebrae of the ox (*Bos taurus* L.). Zentralblatt für Veterinärmedizin C. Anatomie Histologie Embryologie 5, 253-266.

Snedecor, G. W. and Cochran, W. G. (1967). Statistical Methods. Sixth edition. Iowa State University Press, Ames, Iowa, U.S.A.

Spencer, R. P. (1968). Changes in testicular allometric growth curves. Yale Journal of Biology and Medicine 40, 313-319.

Spindler, A. A., Mathias, M. M. and Cramer, D. A. (1980). Growth changes in bovine muscle fiber types as influenced by breed and sex. Journal of Food Science 45, 29-31.

Staun, H. (1963). Various factors affecting number and size of muscle fibers in the pig. Acta Agriculture Scandinavica 13, 293-322.

Tan, G. Y. and Davies, A. S. (1980). Growth of muscle in male and female cattle. Journal of Anatomy 130, 204 (Abstract)

Thompson, D'A. W. (1917). On the theory of transformations, or the comparison of related forms. In On Growth and Form Chapter 17, pp. 1026-1095. Second edition, 1942. University Press, Cambridge.

Truscott, T. G., Lang, C. P. and Tulloh, N. M. (1976). A comparison of body composition and tissue distribution of Friesian and Angus steers. Journal of Agricultural Science, Cambridge 87, 1-4.

Truscott, T. G., Wood, J. D. and Denny, H. R. (1980). Growth and cellularity of fat depots in British Friesian and Hereford cattle. 26th European Meeting of Meat Research Workers, Colarado Springs, 1980, Colarado, U.S.A. Paper A-2, pp. 6-9.

Tulloh, N. M. (1964). The carcass composition of sheep, cattle and pigs as functions of body weight. In Carcass Composition and Appraisal of Meat Animals, Technical Conference, University of Melbourne, 1963, pp. 5-1 to 5-30 (ed. D. E. Tribe). East Melbourne: CSIRO.

Vaughan, H. S., Aziz-ullah, Goldspink, G. and Nowell, N. W. (1974). Sex and stock differences in the histochemical myofibrillar adenosine triphosphatase reaction in the soleus muscle of the mouse. Journal of Histchemistry and Cytochemistry 22, 155-159.

Vezinhet, A. and Prud'hon, M. (1975). Evolution of various adipose deposits in growing rabbits and sheep. Animal Production 20, 363-370.

Walker, D. E. (1961). A study of the growth and development of Jersey cattle. I. A new carcass dissection technique. New Zealand Journal of Agricultural Research 4, 99-122.

Williams, D. R. and Bergström, P. L. (1976). Anatomical jointing, tissue separation and weight recording proposed as the E.E.C. standard method for beef. Memorandum prepared for the Scientific Sub-Group "Carcass and Meat Quality" of the E.E.C. Programme for Co-ordination of Research on Beef Production. pp. 1-27.

Wilson, L. L. (1973). Effects of sire, calf sex and age, and age of dam on birth weight and body dimensions at one and three days of age. Journal of Animal Science 36, 452-456.

Wilson, L. L., Roth, H. B., Ziegler, J. H. and Sink, J. D. (1977). Bovine metacarpal and metatarsal dimensions: Sex effects, heritability estimates and relation to growth and carcass characteristics. Journal of Animal Science 44, 932-938.

Wood, J. D., Enser, M. B. and Restall, D. J. (1975). Fat size in Pietrain and Large White pigs. Journal of Agricultural Science, Cambridge 84,221-225.

Wood, J. D., Enser, M. B. and Restall, D. J. (1978). The cellularity of backfat in growing pigs and its relationship with carcass composition. Animal Production 27, 1-10.

Yeates, N. T. M. (1964). Starvation change and subsequent recovery of adult beef muscles. Journal of Agricultural Science, Cambridge 62, 267-272.