MEASURES OF LEANNESS IN SWINE

By

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INTRODUCTION

A precise objective measure of the lean content of swine is a necessary tool in evaluating the worth of potential breeding animals, in determining the value of various nutritional regimes, and in assessing the merits of different management systems. Continued progress in these three facets of the swine industry has created a need for predictive measures which detect differences at ever narrowing intervals. The primary interrelations between carcass composition and nutrition and management have been set forth. Progress today hinges on the realization of more subtle relationships which have hitherto been undetectable. The nutritionist, for example, is not so interested in the broad relationship between carcass quality and energy levels--this is known--but rather his interest is in protein-energy-carcass interrelations within relatively narrow ranges. Similarly the animal breeder wishes to detect superior animals, not in the population as a whole, but within reasonably uniform herds and lines.

Full elucidation of all interrelating factors among breeding, feeding, and management will surely necessitate continued improvement in carcass evaluation. The futility of attempting to detect differences which are small relative to the error of measurement used is apparent. Yet the inconclusiveness which so often plagues biological research may stem from this very fact. Clearly the reduction in experimental error that would accompany increased precision in appraising carcasses would be invaluable in swine research.

This study was designed to determine and evaluate the extent to which the prediction of carcass leanness could be enhanced by examining full cross sectional exposures at various parts of the carcass. Experimental pigs, chosen in each of two seasons, were homogeneous for sex (barrows), breed, and weight. Intraseason management was standard.

REVIEW OF LITERATURE

General Considerations

The validity of various indices of carcass leanness as reported in the literature must be tempered by the end point to which they are related. There is no end point which can be measured without error. Moreover the magnitude of error in whatever end point is chosen has been largely a matter of judgment. Pearson (1957) stated that a complete physical separation or a chemical analysis is the only fully reliable end point. There is, however, little evidence available on how precisely carcasses can be separated or can be sampled for chemical analysis in spite of the wide recognition that the separation and the sampling of meat are subject to large error.

The most widely used end point is percent lean cuts. It has an advantage because it can be more readily obtained than complete physical separation or chemical analysis. It has disadvantages because it does not include the belly and because interlaboratory variations exist in the manner in which lean cuts are trimmed. The standardization in laboratory procedures, however, which has come about through the activities of the Reciprocal Meat Conference makes it particularly desirable from an overall practical view, especially in studies involving a large number of carcasses. A measure of its cutting accuracy has been reported by Lasley and Kline (1957) who found an error variance of .649. (The true value of percent lean cuts would be expected to lie in the range of

$\pm$ .805 percent of the observed value about two-thirds of the time.)

Lasley and Kline (1957) have pointed out that the ability of any particular measure to discriminate between two pigs is a function of both the accuracy of the measurement and the real difference between the pigs involved. Indices which will pick up large differences may be quite futile in detecting small differences. Ezekiel (1941) has indicated that, where the accuracy of prediction is interpreted by examining the magnitude of the correlation coefficient, due consideration must be made of the fact that this statistic estimates a ratio parameter whose magnitude usually increases with an increase in the variance of the population. Thus, where experimental material varies widely, the high correlations which generally result can not be applied to uniform populations.

Carcass length, loin eye area, and an average of three to four carcass back fat measurements have become widely accepted and used as standard measures of carcass merit. Some investigators have restricted studies of new procedures to the prediction of loin eye area or carcass back fat thickness. For example, it may be shown that a correlation of .75 exists between average live fat measurements and average carcass back fat measurements. Pearson (1957) has implied that, while loin eye area and carcass back fat are suitable indices of leanness, they are not necessarily satisfactory dependent variables. Ezekiel (1941) has pointed out that, if the relationship between A and B is known and the relationship between A and C is known, the relationship between A and C can not be implied. Hence, the index A which reliably predicts B is not necessarily a good index of C. In the context of swine evaluation, it follows that indices which reliably predict back fat or loin eye area are not necessarily good measures of leanness.

The preceding discussion sets forth some of the difficulties contingent on interpreting and applying the results of the literature on swine carcass evaluation. Notwithstanding the limitations which may be inherent, there is indeed a wealth of valuable knowledge on the subject.

Live Animal Evaluation

Visual Appraisal and External Measurements:

The ability of the eye and the tape measure to predict carcass merit generally has been low. Some improvement has resulted if measurements on various parts of the body are considered jointly. Arthaud and Dickerson (1952) found correlations between nine individual live scores and lean cuts all to be below .32. Essentially the same results were obtained by Lasley et al. (1957) who studied the relationship between seven scores and percent primal cuts. Bratzler and Margerum (1953) found live scores of length, of back fat, and of preferred cut yield were more accurate on light hogs (180 to 200 pounds) than on heavy hogs (220 to 240 pounds). For light and heavy carcasses respectively, the correlations between length score and carcass length were .60 and .15, between fat score and carcass back fat were .50 and .20, and between yield score and preferred cut yield were .28 and .20. A correlation of .56 between condition score and percent lean cuts, which reduced to .25 on an intra-analysis, was reported by Holland and Hazel (1958).

Hetzer et al. (1950) obtained correlations in the range of .02 to .50 for various live measurements (height, length, width, and depth at different points) and the percent yield of five primal cuts. When a total of eight measurements were combined, a correlation of .68 was obtained. Robison et al. (1960) were able to obtain a correlation of .79

with percent lean cuts by combining seven live measurements. This value was similar to that obtained from the average of live probes taken at two sites. Holland and Hazel (1958) and Wilson _et al._ (1958) studied essentially the same measurements as Hetzer _et al._ (1950) and obtained low correlations with percent lean cuts. They did not combine their measurements into multiple regression studies. Their data indicated, however, that any individual probe measure is superior to an individual external measure.

These investigations indicate that live measurements, if plentiful, will have reasonable predictive power. There is also a suggestion that their predictive ability will not exceed that of the live probe. The extent to which live tape measurements and probe measurements might supplement one another has not been investigated.

Live Measurements of Back Fat Thickness:

The ruler probe developed by Hazel and Kline (1952), the lean meter developed by Andrews and Whaley (1954), the ultrasonic devices, and the x-ray techniques have been used to measure fat depth on the live hog. Where comparisons have been made (Dumont and Destandau, 1959; Hazel and Kline, 1959; Pearson _et al._, 1957; Price _et al._, 1960b), it is not possible to discriminate among the four methods. Each appears equally accurate if used by an experienced technican. Moreover various live measurement techniques usually have been equal to or superior to carcass back fat measurements as indicators of carcass leanness where comparisons have been made (Hazel and Kline, 1952; Hazel and Kline, 1959; Hetzer _et al._, 1956; Holland and Hazel, 1958; Pearson _et al._, 1957; Pearson _et al._, 1958; Price _et al._, 1957; Price _et al._, 1960b). In a few investigations carcass back fat has shown a slight advantage (De Pape, 1954; Hazel and

Kline, 1953; Hetzer _et al_., 1950; Zobrisky _et al_., 1959). Single probe measures have proven unsatisfactory and the necessity of taking at least three or four readings is well established (De Pape, 1954; Hazel and Kline, 1953; Holland and Hazel, 1959; Price _et al_., 1960).

The correlations between live probes and percent lean cuts reported by the workers quoted above generally have been in the range of .70 to .80. On occasion they have reached .90 (Hazel and Kline, 1959) and have been as low as .44 (Zobrisky _et al_., 1959). The causes of these wide variations are not readily apparent.

In general, the literature indicates that live probe fat measurements on swine are reliable indices of carcass merit which might be expected to explain 50 to 60 percent of the variation in percent lean cuts. As indices these measurements are equal to carcass back fat measurements. This is not surprising when it is noted that live probes are taken on the animal standing in a more or less normal condition, and are taken off the central axis of the body where they are free from interference of the vertebral column. This contrasts to carcass fat measurements which are taken over the longitudinal axis of the back after the carcass has been subjected to the distortion of both unequal splitting and unequal shrinkage.

Measurements of Lean on the Live Hog:

Holland and Hazel (1958) were unable to predict percent lean cuts from mechanical probes of the depth of lean over the scapula and ilium. Their correlations were .18 and .00 respectively. Using an ultrasonic device, Price _et al_. (1960b) measured the depth of the _longissimus dorsi_ and obtained a correlation of .22 with percent lean cuts. Stouffer (1959) described a method of obtaining loin eye area from ultrasonic reflections.

This method has been employed by Price et al. (1960a) who obtained a correlation of .74 between live estimated areas and areas from subsequent tracings on 41 pigs. The authors concluded that the method was time consuming, tedious, and required further refinement to be useful. In a similar study, Zobrisky et al. (1960) obtained a correlation of .84 between live estimated loin eye areas and actual loin eye tracings on 69 hogs.

The value of measuring the lean in the live hog is not yet evident. More data is required to appraise the potential of ultrasonics in measuring loin eye area. Even if improved techniques result in good appraisal, the relationship between loin eye area and carcass merit sets an upper limit on accuracy.

Physiological Measurements of Live Hogs:

Blood fat levels of live hogs have been reported to be related to back fat thickness ($r = .36$)(Bowland and Hironka, 1957). Correlations of creatinine level in urine and in blood with percent lean cuts have been reported to be .65 and .33 respectively (Saffle et al., 1960). The preferential absorption of "antipyrine" by body water, of cyclopropane and of nitrogen by body fat, and the duration of "sleep" of pigs drugged with fat soluble organic compounds have been put forth as methods of estimating body composition (Clawson et al., 1955; Feinstein, 1955). In the latter two investigations, there were extreme variations in the experimental animals. The numbers of animals used were ten and twenty-nine respectively.

For the most part, physiological measurements have not proven to be particularly reliable indices of carcass merit and the technical difficulties and labor of such methods would seem to preclude their wide use.

Carcass Evaluation

The classical works on carcass evaluation were conducted by McMeekan (1940 and 1941), Warner et al. (1934), and Hankins and Ellis (1934). These early studies set forth the utility of back fat measurements, loin eye area, and length as indices of merit and paved the way for objective carcass appraisal. Their interests were in broad relationships and their experimental material was chosen accordingly. This permitted them to display basic linear relations among carcass traits even over extended ranges. While linearity may not be true in the strictest sense, these studies do provide a measure of confidence that data in a more restricted range can be treated as linear without substantial error.

A second series of publications stimulated by a renewed interest in carcass grading appeared early in the 1950's (Cummings and Winters, 1953; Reynolds and Kiehl, 1952; Henning and Evans, 1953). The extensive nature of these studies established that carcass weight, back fat thickness and, to a lesser extent, length were admirably suited to sorting carcasses into broad classes indicative of true value. Their failure to study the value of loin eye area and to point out the precision by which relatively uniform carcasses can be appraised limits their application in the experimental field.

Carcass Back Fat, Loin Eye Area, Length, and Specific Gravity:

Recent results showing the relationship of these four traits with percent lean cuts are tabulated in Table I. Where overall and intra-analyses were performed, only results of the intra-analyses were included. Three pertinent features characterize these data: first, as a measure of leanness, specific gravity is usually superior to either carcass back fat thickness, loin eye area, or length; second, back fat measurements generally have been more closely related to leanness than has loin eye area; and third, the extreme variation in correlations between length and percent lean cuts casts doubt on the reliability of length as an index of leanness.

TABLE I

CORRELATIONS OF CARCASS BACK FAT, LOIN EYE AREA, LENGTH, AND SPECIFIC GRAVITY WITH PERCENT LEAN CUTS

	Carcass Trait					
Trait	Back Fat	Loin Eye Area	Length	Specific Gravity	Number of Pigs	Source
Percent Lean Cuts	-.72	.51	.54	.84	66	Brown et al., 1951
	-.72	.50	.02	.65	36	Price et al., 1957
	-.78	.68	.82	.87	101	Whiteman & Whatley, 1953
	-.59	.46	.74	.65	102	Whiteman & Whatley, 1953
	-.33		.24	.71	103	Pearson et al., 1956a
	-.56	.42	.25		105	Holland & Hazel, 1958
	-.42	.60	-.18		108	Zobrisky et al., 1959
	-.69	.35	.12		30	Aunan & Winters, 1949
	-.82	.62			84	Price et al., 1960b
	-.80		.57		142	Pearson et al., 1959
		.53	.28		102	Pearson et al., 1956b

Where multiple regression has been employed, the joint predictive value of specific gravity and other indices of leanness has remained essentially the same as that of specific gravity (Brown et al., 1951; Whiteman et al., 1953). Also the predictive ability of back fat and length has shown little advantage over that of back fat (Henning and Evans, 1953; Price et al., 1960b). However, joint consideration of back fat and loin eye area by Holland and Hazel (1958) resulted in a multiple correlation of .70 with percent lean cuts compared to simple correlations of -.56 and .42 respectively.

The studies which have considered multiple regression are as yet too restricted to clearly establish the value of jointly considering several simple indices. The evidence which is available does suggest that the improvement which will result is likely to be modest. By the extent to which this is so and by virtue of the predictive ability of the live probe, the information from conventional carcass measurements may not excel that which can be realized from the live animal. Further research is needed to clarify this point.

Lean Content of Part of the Carcass:

Particularly high correlations ranging from .73 to .96 have been reported between percent trimmed ham and percent lean cuts (Hazel and Kline, 1959; Hetzer *et al*., 1953; Pearson *et al*., 1958; Smith *et al*., 1957; Whiteman and Whatley, 1953; Zobrisky *et al*., 1959). Almost equally high values (r = .74 to .88) have been reported between percent trimmed loin and percent lean cuts (Aunan and Winters, 1949; Pearson *et al*., 1958a; Zobrisky *et al*., 1959). Moreover the correlation of these two indices with percent lean cuts has tended to be appreciably higher than those given by other indices in each of the various reports.

There is a theoretical argument that such correlations are unavoidably large because of their part-whole relation. While this is true such a relationship should not invalidate predictive ability, nor is it apparent why the correlation should not be as reliable an indicator of prediction here as elsewhere. The literature surely establishes that determination of the lean content of a major wholesale cut is one of the more accurate ways of estimating the lean content of the carcass.

Potassium Content of Lean Meat:

The potassium content of lean meat does not vary widely; further, of the potassium present a constant portion is in the form of radioactive potassium-40. Thus, barring other contamination, the activity of K40 in an animal may accurately portray its lean content. Kulwich et al. (1961) have developed this concept and applied it to 44 hams. A correlation of .96 between the activity of K40 and percent lean was realized. In view of the close relationship between the lean of the ham and that of the carcass, the method has unlimited scope. Its practicability is not yet clear. Kirton et al. (1961) conducted a similar investigation on ten live sheep. Their results were not encouraging and the authors questioned the usefulness of the method.

Two Measurements Indices:

Frequently workers have attempted to improve predictability by combining two measurements into a single index. Cummings and Winters (1953), for example, developed a "T" factor which represented the ratio of back fat thickness to carcass length. Pearson et al. (1958a) used a "loin" index which was the trimmed loin as a percent of the rough loin. These workers also studied (1958b) an index composed of the ratio between the trimmed loin and average back fat thickness. Pearson et al. (1956b) considered the ratio between lean and fat in cross sectional tracings of the rough loin. Usually these indices have given moderately higher correlations with percent lean cuts than have the individual simple measurements. Whether they are simply multiple regression in disguise is not clear. For example, had Cummings and Winters (1953) used carcass back fat and length in a multiple regression equation, the predictive value might have been similar to that obtained by their "T" factor.

The whole concept of how dependent variables should be combined is controversial. From a theoretical view multiple regression would likely be preferred. Conventionally this has not been the case. This is so not only in the examples cited above but also in the use of all percentage figures which do nothing more than combine two variables into one. This general area is confusing and the literature to date provides little clarification.

Interrelationships Among Conventional Traits:

The value of a trait can be determined solely by how accurately it predicts the desired end point. Where results are as variable, however, as they are in the area of swine carcass evaluation, there is merit in examining the correlations among the various indices. Table II was constructed by choosing from the literature representative correlations among five traits: live back fat (ruler probe), carcass back fat, loin eye area, length, and specific gravity. Ultrasonic and lean meter data were excluded in that they portray essentially the same relationships given by the ruler probe. The pertinent feature of this table is the variability it displays. The correlations between length and each other trait are low; with loin eye area it is not even consistent in direction. As would be expected, the live ruler probe measurements are closely associated with carcass back fat. The relationships, however, among back fat thickness, specific gravity, and loin eye area, though consistent in direction, are not especially strong.

TABLE II

REPRESENTATIVE PHENOTYPIC CORRELATIONS AMONG FIVE CARCASS TRAITS USED TO EVALUATE SWINE CARCASSES

Trait	Ruler Probe	Loin Eye Area	Length	Specific Gravity
Carcass Back Fat	.70 (k)[1]	-.15 (h)	-.09 (m)	-.30 (c)
	.72 (g)	-.18 (m)	-.11 (c)	-.48 (o)
	.81 (f)	-.28 (c)	-.27 (e)	-.59 (k)
	.87 (m)	-.37 (a)	-.39 (i)	-.68 (a)
	.90 (n)	-.43 (o)	-.62 (a)	-.75 (o)
Ruler Probe		-.14 (h)	-.03 (m)	-.56 (j)
		-.21 (m)	-.33 (c)	-.56 (k)
		-.44 (h)	-.38 (k)	-.61 (m)
		-.69 (n)		-.74 (n)
Loin Eye Area			-.07 (e)	.34 (o)
			-.02 (b)	.46 (a)
			.10 (d)	.53 (j)
			.33 (m)	.61 (m)
			.38 (l)	.60 (o)

[1]Reference and number of pigs involved:

(a) Brown *et al.*, 1951--66 pigs
(b) Cummings & Winters, 1953--708 pigs
(c) De Pape, 1954--73 pigs
(d) Enfield & Whatley, 1961--531 pigs

(e) Fredeen, 1953--6876 pigs
(f) Hazel & Kline, 1952--96 pigs
(g) Hetzer *et al.*, 1956--140 pigs
(h) Holland & Hazel, 1958--105 pigs

(i) Lush, 1936--1285 litters
(j) Pearson *et al.*, 1956a--103 pigs
(k) Pearson *et al.*, 1957--99 pigs
(l) Pearson *et al.*, 1959--142 pigs

(m) Price *et al.*, 1957--36 pigs
(n) Saffle *et al.*, 1958--35 pigs
(o) Whiteman *et al.*, 1953--101 pigs

The phenotypic correlations, while of value in determining the accuracy of appraisal, do not indicate because of their environmental and genetic components what might happen under selection. This is determined by the genetic correlation. Genetic correlations among carcass traits are not plentiful. Those available are tabulated in Table III. The direction of these correlations rather than their magnitude is possibly their important feature. Particularly apparent is the antagonistic relation between length and loin eye area. This, coupled with the fact that length has shown a consistent negative genetic correlation with back fat, implies an increase in length may be inevitable but should not be sought after from a strictly carcass view. Certainly the literature here, as in the case of phenotypic correlations, raised doubts of the value of length in carcass appraisal.

TABLE III

GENETIC CORRELATIONS AMONG FOUR CARCASS TRAITS USED TO EVALUATE SWINE CARCASSES

Trait	Length			Loin Eye	Percent Lean Cuts
Back Fat	-.19 (b)[1]	-.24 (e)	-.24 (e)	-.08 (d)	-2.66 (c)
	-.27 (d)	-.42 (f)	-.46 (c)	-.10 (b)	-1.15 (a)
		-1.24 (a)			
Length				-.14 (b)	-.48 (c)
				-.17 (d)	.65 (a)

[1]Reference and number of pigs involved:

(a) Anderson, 1954--550 pigs
(b) Enfield and Whatley, 1961--531 pigs
(c) De Pape, 1954--341 pigs
(d) Fredeen, 1953--6876 pigs
(e) Fredeen and Jonsson, 1957--1872 pigs
(f) Johansson and Korkman, 1950--1208 litters

The indices reviewed constitute those which have stirred interest and those which form the basic core of carcass appraisal. There are many variants which, as yet, have not shown sufficient uniqueness to justify their inclusion.

MATERIALS AND METHODS

Twenty-one barrows in each of two seasons were picked from groups of about 60 crossbred barrows originating from reciprocal matings between a Duroc line (OK8) and a Beltsville No. 1 line (OK9) maintained at the Oklahoma Station. In Season I (spring, 1960) birth and rearing occurred at the Stillwater Station where a ration of shelled corn and supplement was self-fed on pasture. In Season II (fall, 1960) birth and rearing occurred at the Fort Reno Station where a ration of ground wheat and supplement was self-fed in confinement.

Experimental animals were chosen arbitrarily from those weighing approximately 200 to 215 pounds at regular weekly weighings. In that choices were made over the time period in which members of the groups reached appropriate weights, the overall scheme of choosing was considered random.

Slaughtering was conducted at the University Meat Laboratory on the day following regular weigh off and after the animals had undergone a 24- to 30-hour shrinkage. At slaughter the head, leaf lard and kidneys were removed but the carcass was not split because it was believed that splitting could be done more accurately after chilling had occurred.

After a 72-hour chill each carcass was split. Each side was then broken down as follows:

(a) The shoulder was removed perpendicular to the axis of the body at the junction of the second and third thoracic vertebrae.

(b) The ham was removed perpendicular to the axis of the hind leg at the junction of the second and third sacral vertebrae and was then divided perpendicular to the axis of the hind leg as follows:

(i) The butt was removed across the fullness of the semimembranosus.

(ii) The shank was divided at a point 1 1/2 inches anterior to a meat skewer which was inserted into the stifle joint.

(c) Removal of the ham and the shoulder left the center of the side intact. This piece, which has been designated the middle, was divided perpendicular to the axis of the body at four points as follows:

(i) the junction of the sixth and seventh thoracic vertebrae.

(ii) the junction of the tenth and eleventh thoracic vertebrae.

(iii) four vertebrae posterior to (ii).

(iv) the junction of the fifth and fourth last lumbar vertebrae (the anterior edge of the lumbar vertebra that was three vertebrae anterior to the last lumbar vertebra).

This procedure[1] divided the carcass into nine sections. A skeletal diagram of the pig showing the location of each cut is given in Figure 1 (Page 21). Cross sectional tracings of the fat-muscle-bone content of the anterior face of each section were made on transparent acetate.

The ham, the middle, and the shoulder from each side were separated into fat (which included skin), bone, and lean. The front and rear feet were not skinned out and their respective weights were included with the bones of the shoulder and the ham. All ribs were individually separated. To restrict evaporation loss, all separation was conducted in a high

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[1]An initial attempt to section the shoulder at the second-third and the fifth-sixth cervical vertebrae was abandoned because of inability to cut the humerous at a consistent point.

humidity cooler and exposed tissues were covered with damp cloths to the extent that it was practical.

Samples of about 100 grams were obtained for chemical analysis from the separable lean of each side according to the following procedure. The total lean of each side was ground through a 3/8 inch plate, hand blended, and reground through a 1/8 inch plate. During the course of the second grinding, nine three- to four-gram samples were randomly drawn from each one-third of the composite side.

The following additional data were obtained on each side:

(a) Live back fat[1]: Prior to slaughter, shoulder probes and loin probes were taken of the fat depth with the lean meter at points one to two inches off the center of the back at approximately the fourth to seventh rib and the mid-loin respectively. The established procedure was to take repeat readings if the corresponding left-right measurements failed to agree within one-tenth inch. Few repeats were necessary. When they were taken, the final measurements recorded were based on a judgment decision.

(b) Carcass back fat: Thickness of back fat was obtained at the first rib, seventh rib, last rib, and last lumbar vertebra.

(c) Carcass length: Length measurements were made from the anterior edge of the aitch bone to the anterior edge of the first rib.

(d) Specific gravity: Specific gravity of the ham, the middle, and the shoulder were obtained by water displacement. Air and water readings were composited to obtain specific gravity of the half and the whole carcass. Water weights were made to the nearest gram.

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[1]Because three pigs in Season II were not probed, all live probe data are based on 39 pigs.

From each cross sectional tracing, planimeter readings were obtained of the areas of lean, bone, and certain muscle groups which are set forth in Table IV and Figures 2 to 9. Fat area was obtained by subtracting the areas of lean and bone from the total area. Tracings made through parts of the body containing ribs showed inconsistent amounts of rib bone and rib lean because the cut tended to transverse several ribs. To circumvent the inconsistency that this would contribute to area measurements, the rib and vertebral contributions of each tracing were eliminated by drawing a boundary line corresponding to the point of removal of the rib and vertebra from the carcass. The position of the line was readily established. Where lean area in a tracing was expressed as a percentage, the contribution of all internal bone as well as that of the rib and vertebra was eliminated.

Records of air weights of tissues were made to the nearest one-tenth pound; of linear measurements, to the nearest one-tenth inch; of area measurements, to the nearest one-hundredth square inch. Statistical calculations were done on an IBM 650 data processing machine.

TABLE IV

CODE, LOCATION, AND MUSCLE GROUPS FOR EACH OF EIGHT CROSS SECTIONS

Cross Section Code	Cross Section Location	Muscle Group	Muscle Nomenclature
CS2T	2nd-3rd Thoracic Vertebrae	1	Longissimus dorsi
		2	Trapezius thoracis, Rhomboideus, Spinalis, Multifidus dorsi, Serratus ventralis, Ilio-costalis
		3	Supraspinatus, Latissimus dorsi, Subscapularis, Infraspinatus, Tensor fascia antibrachii, Caput laterale tricipitis, Pectoralis profundus

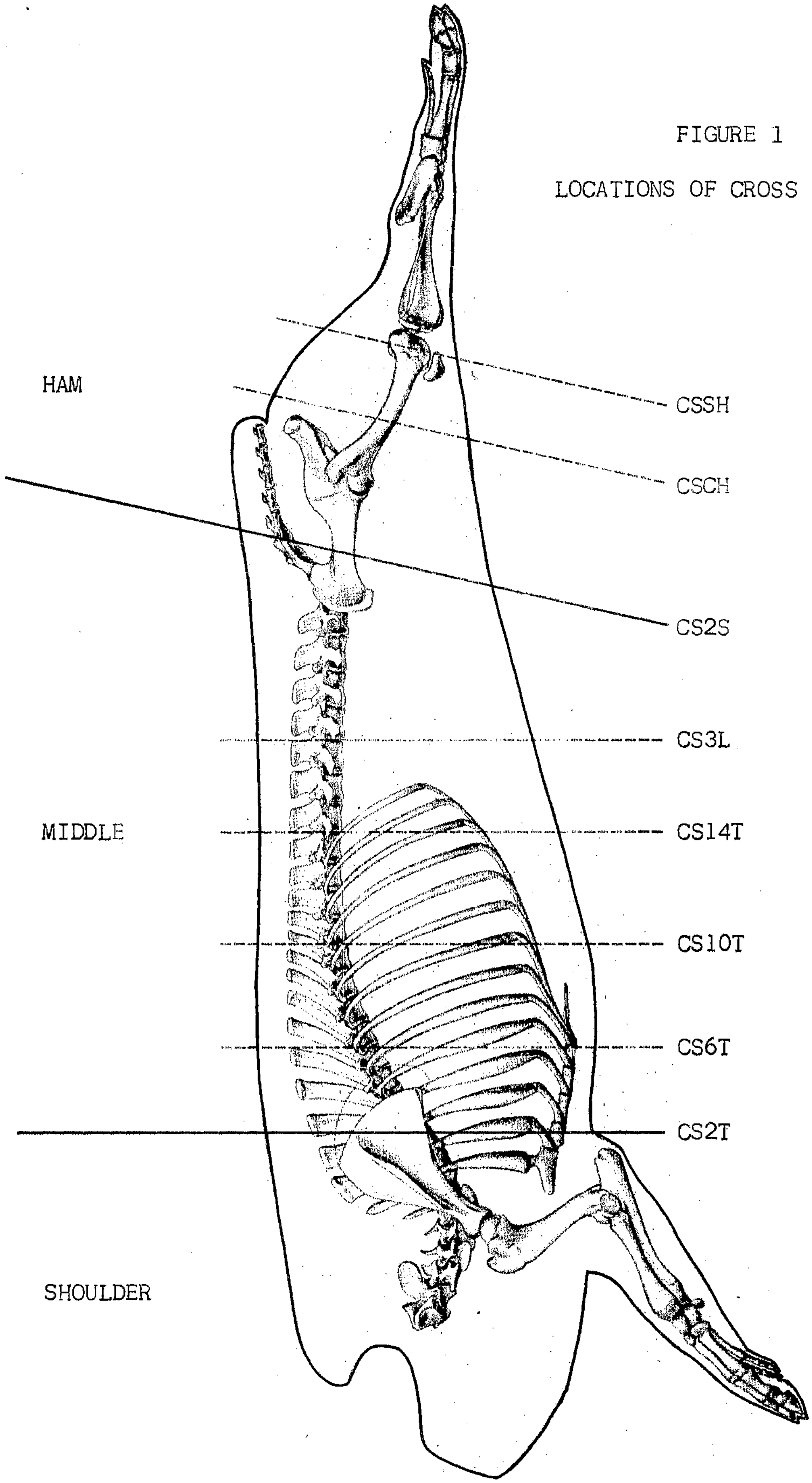
Table IV (Continued)

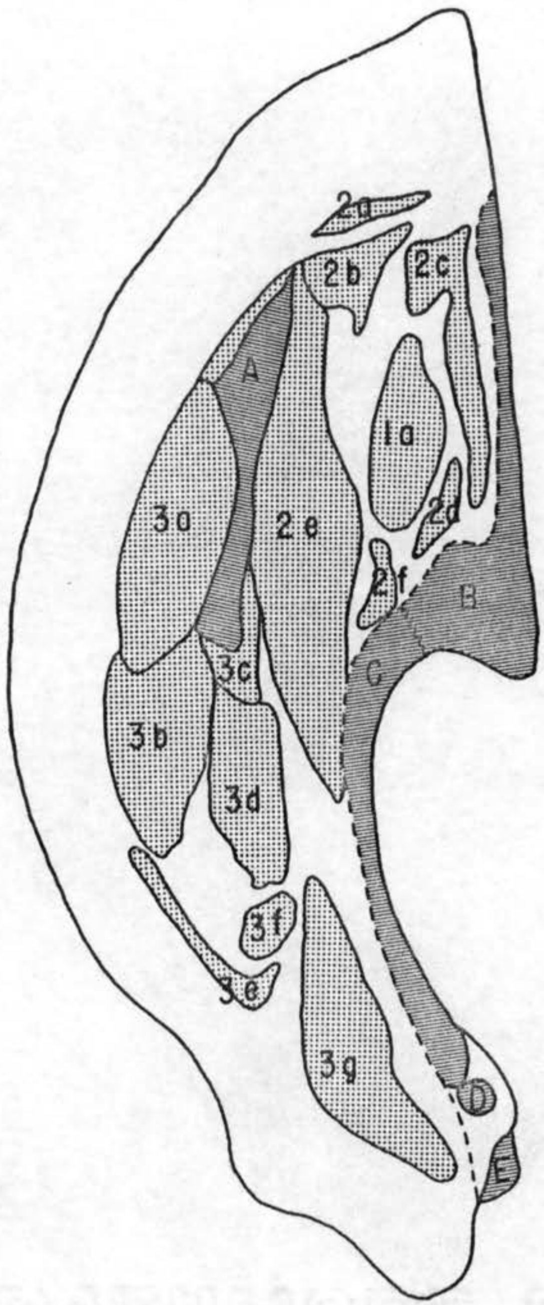
Cross Section Code	Location	Muscle Group	Muscle Nomenclature
CS6T	6th-7th Thoracic Vertebrae	1	Longissimus dorsi
		2	Trapezius thoracis, Spinalis, Multifidus dorsi
		3	Latissimus dorsi, Serratus dorsalis, Longissimus costarum, Serratus ventralis, Obliquus abdominis externus
		4	Cutaneous muscle, Pectoralis profundus
CS10T	10th-11th Thoracic Vertebrae	1	Longissimus dorsi
		2	Spinalis, Multifidus dorsi
		3	Latissimus dorsi, Longissimus costarum, Serratus thoracic digitations, Obliquus abdominus externus, Obliquus abdominis internus, Pectoralis profundus, Rectus abdominis
		4	Cutaneous muscle
CS14T	Four Vertebrae Posterior to CS10T[1]	1	Longissimus dorsi
		2	Multifidus dorsi, Spinalis, Semispinalis
		3	Longissimus costarum, Serratus dorsalis, Obliquus abdominis externus, Rectus abdominis, Obliquus abdominis internus
		4	Cutaneous muscle
CS3L	Anterior Edge of 4th Last Lumbar Vertebra[2]	1	Longissimus dorsi
		2	Spinalis, Multifidus dorsi, Quadratus lumborum, Iliopsoas, Psoas minor
		3	Obliquus abdominis externus, Transversus abdominis, Obliquus abdominis internus
		4	Cutaneous muscle, Rectus abdominis
CS2S	2nd-3rd Sacral Vertebrae	1	Multifidus dorsi, Piriformis, Gluteus medius, Tensor fascia latae
		2	Gluteus accessorius, Gluteus profundus, Iliopsoas, Rectus femoris, Psoas minor
		3	Transversus abdominis, Rectus abdominis, Cutaneous muscle
CSCH	Center of the Ham	1	Vastus lateralis, Vastus medialis, Rectus femoris, Vastus intermedius
		2	Semimembranosus, Gracilis
		3	Semitendinosus
		4	Biceps femoris
CSSH	Shank of the Ham	1	Adductor, Vastus lateralis
		2	Biceps femoris
		3	Semitendinosus
		4	Semimembranosus, Gracilis

[1]Designated the cross section at the 14th thoracic vertebra.
[2]Designated the cross section at the 3rd lumbar vertebra.

FIGURE 1

LOCATIONS OF CROSS SECTIONS





Group Muscle

1 a - Longissimus dorsi

2 a - Trapezius thoracis
b - Rhomboideus
c - Spinalis
d - Multifidus dorsi
e - Serratus ventralis
f - Ilio-costalis

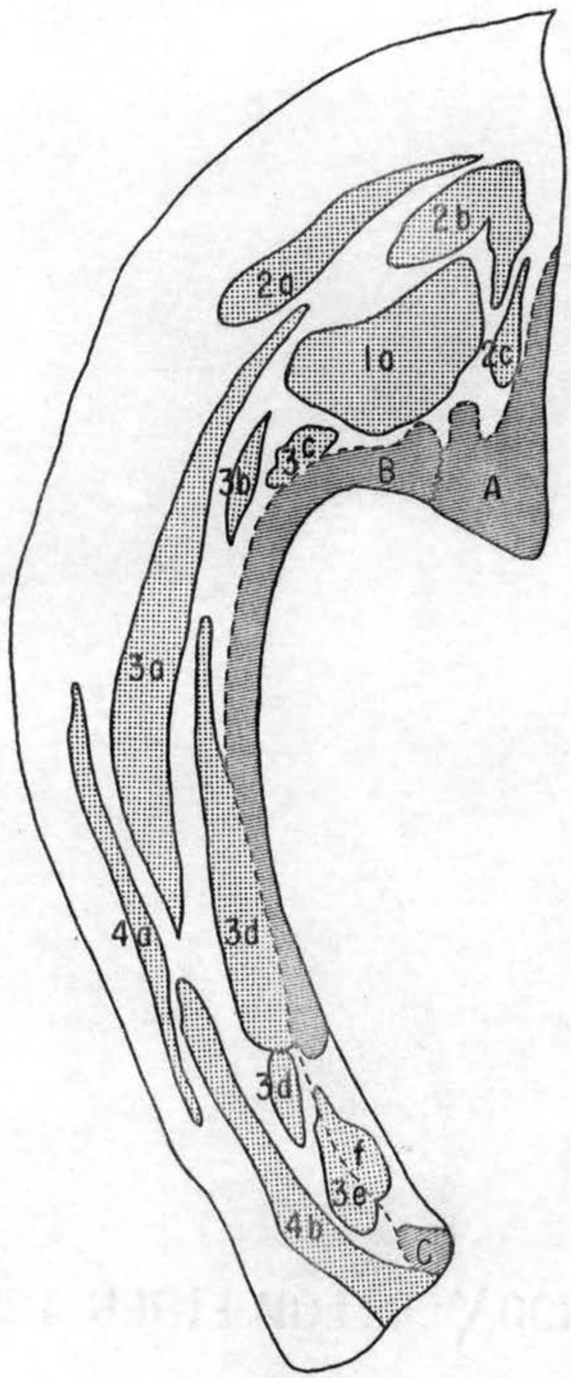
3 a - Supraspinatus
b - Latissimus dorsi
c - Subscapularis
d - Infraspinatus
e - Tensor fascia antibrachii
f - Caput laterale tricipitis
g - Pectoralis profundus

Bone and Cartilage

A - Scapula
B - Thoracic vertebra and spinous process
C - Intercostal
D - Cartilage Tips
E - Sternum

----- Line eliminating rib and vertebra

FIGURE 2. CROSS SECTION AT THE SECOND AND THIRD THORACIC VERTEBRAE (CS2T)



Group Muscle

1 a - Longissimus dorsi

2 a - Trapezius thoracic
b - Spinalis
c - Multifidus dorsi

3 a - Latissimus dorsi
b - Serratus dorsalis
c - Longissimus costarum
d - Serratus ventralis
e - Obliquus abdominis externus

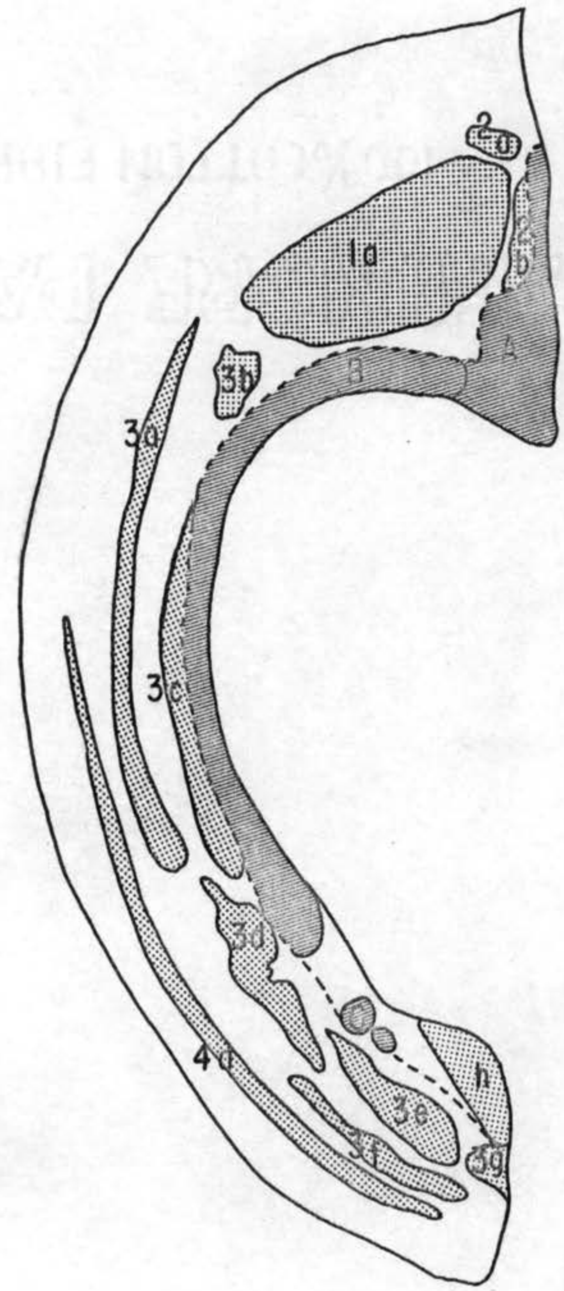
4 a - Cutaneous muscle
b - Pectoralis profundus

Bone

A - Thoracic vertebra and spinous process
B - Intercostal
C - Sternum

----- Line eliminating bone and (f) transversus thoracis

FIGURE 3. CROSS SECTION AT THE SIXTH AND SEVENTH THORACIC VERTEBRAE (CS6T)



Group Muscle

1 a - Longissimus dorsi

2 a - Spinalis
b - Multifidus dorsi

3 a - Latissimus dorsi
b - Longissimus costarum
c - Serratus thoracic digitations
d - Obliquus abdominus externus
e - Obliquus abdominis internus
f - Pectoralis profundus
g - Rectus abdominis

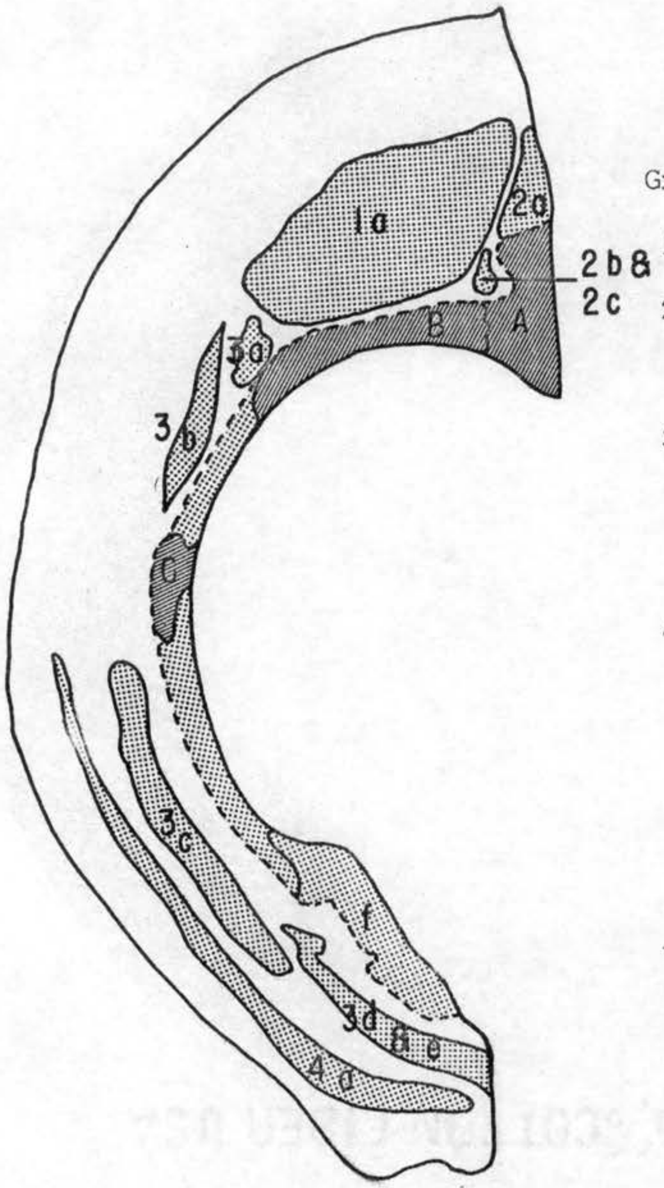
4 a - Cutaneous muscle

Bone and Cartilage

A - Thoracic vertebra and spinous process
B - Intercostal
C - Cartilage tips

----- Line eliminating bone and (h) transversus abdominis

FIGURE 4. CROSS SECTION AT THE TENTH AND ELEVENTH THORACIC VERTEBRAE (CS10T)



Group Muscle

1 a - Longissimus dorsi

2 a - Multifidus dorsi
b - Spinalis
c - Semispinalis

3 a - Longissimus costarum
b - Serratus dorsalis
c - Obliquus abdominis externus
d - Rectus abdominis
e - Obliquus abdominis internus

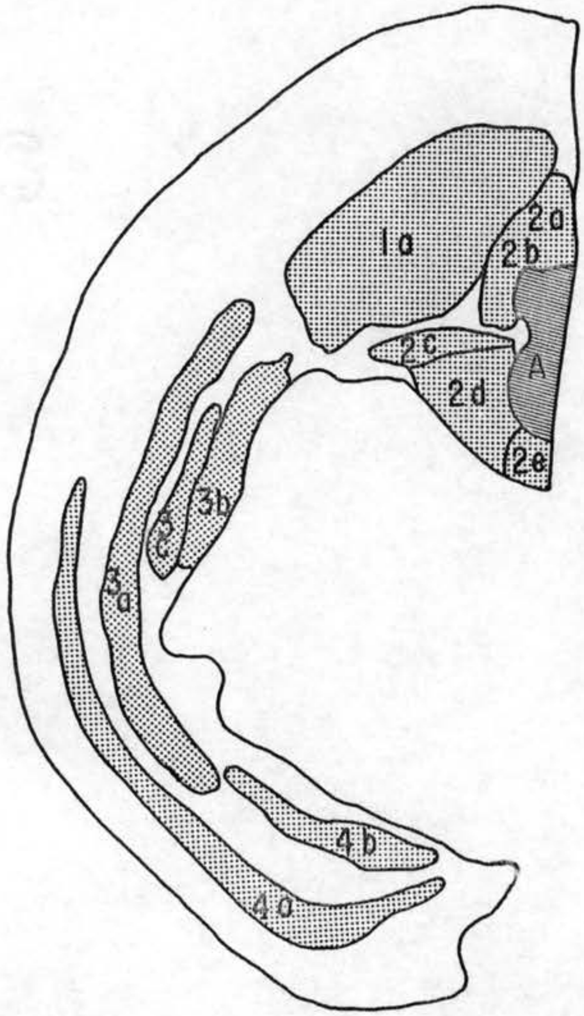
4 a - Cutaneous muscle

Bone

A - Lumbar vertebra
B - Intercostal
C - Costal

----- Line eliminating bone and (f) transversus abdominis

FIGURE 5. CROSS SECTION FOUR VERTEBRAE POSTERIOR TO CS10T (CS14T)



Group Muscle

1 a - Longissimus dorsi

2 a - Spinalis
  b - Multifidus dorsi
  c - Quadratus lumborum
  d - Iliopsoas
  e - Psoas minor

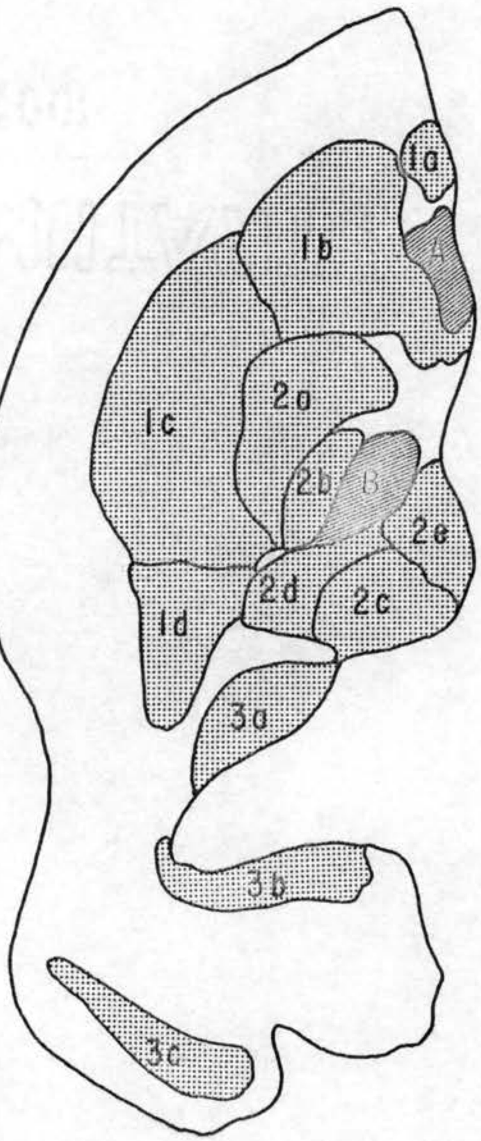
3 a - Obliquus abdominis externus
  b - Transversus abdominis
  c - Obliquus abdominis internus

4 a - Cutaneous muscle
  b - Rectus abdominis

Bone

A - Lumbar vertebra

FIGURE 6. CROSS SECTION AT THE ANTERIOR EDGE OF THE FOURTH LAST LUMBAR VERTEBRA (CS3L)

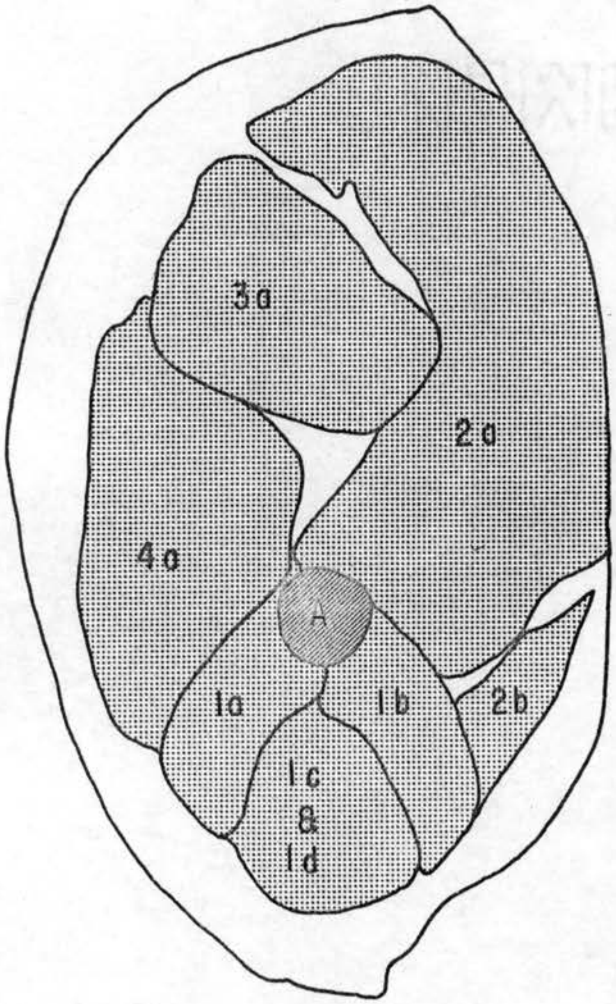


Group	Muscle
1 a	Multifidus dorsi
b	Piriformis
c	Gluteus medius
d	Tensor fascia latae
2 a	Gluteus accessorius
b	Gluteus profundus
c	Iliopsoas
d	Rectus femoris
e	Psoas minor
3 a	Transversus abdominis
b	Rectus abdominis
c	Cutaneous muscle

Bone

A - Sacral vertebra
B - Ilium

FIGURE 7. CROSS SECTION AT THE SECOND AND THIRD SACRAL VERTEBRAE (CS2S)



Group Muscle

1 a - Vastus lateralis
  b - Vastus medialis
  c - Rectus femoris
  d - Vastus intermedius

2 a - Semimembranosus
  b - Gracilis

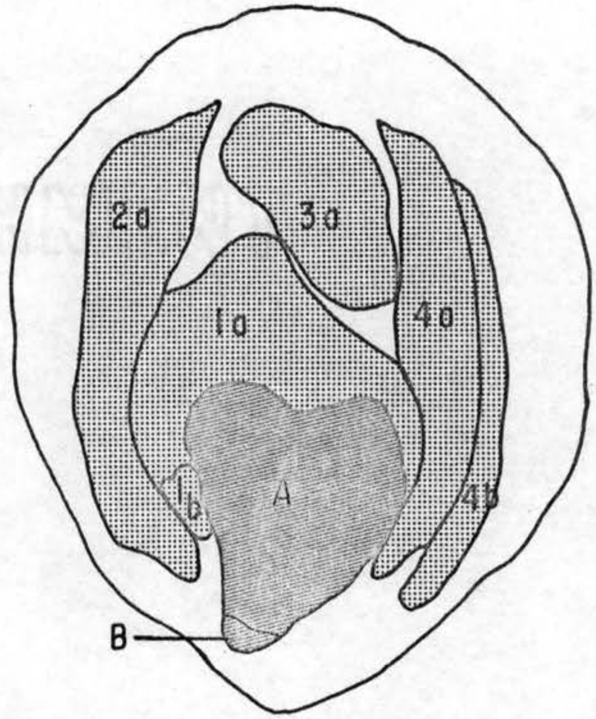
3 a - Semitendinosus

4 a - Biceps femoris

Bone

A - Femur

FIGURE 8. CROSS SECTION AT THE CENTER OF THE HAM
(CSCH)



Group Muscle

1 a - Adductor
  b - Vastus lateralis

2 a - Biceps femoris

3 a - Semitendinosus

4 a - Semimembranosus
  b - Gracilis

Bone

A - Femur
B - Patella

FIGURE 9. CROSS SECTION OF THE SHANK OF THE HAM

DESCRIPTION OF DATA

The pigs of Season II compared with those of Season I were heavier and older at slaughter, possessed less back fat, larger loin eyes, distinctly leaner carcasses, and were somewhat more uniform (Table V).

TABLE V

SEASONAL MEANS AND STANDARD DEVIATIONS FOR SEVEN TRAITS

Trait	Season I Mean	Season I St. Dev.	Season II Mean	Season II St. Dev.
Shrunk Weight (Lbs.)	195.2	5.49	200.0	5.59
Cold Carcass Wt. (Lbs.)	136.5	8.85	142.3	4.34
Age (Days)	159.5	11.34	166.1	13.78
Separable Lean (Lbs.)	54.8	5.59	59.8	4.72
Av. Live Probe (In.)	1.68	.16	1.48	.11
Av. Car. Back Fat (In.)	1.57	.20	1.37	.13
Av. Loin Eye Area at 10th Rib (S. In.)	3.44	.50	3.71	.42

The presence or absence of bilateral asymmetry was investigated by obtaining repeatabilities (intraclass correlations) of the right-left differences of loin eye areas at four points, and of the right-left differences of the lean of the shoulder, the middle, and the ham (Tables VI and VII). The validity of such repeatabilities to establish or disprove symmetry hinges on the supposition that the nature of a difference at one point of the body should be repeated at adjacent points if asymmetry prevails. The failure of differences to be repeatable would suggest symmetry, and would indicate that the differences observed were random elements free of any pig component. The intraclass correlations obtained were -.02 for the right-left differences of loin eye areas and -.08 for the right-left differences of the lean of the shoulder, the middle, and the ham. These small correlations suggest that any asymmetry displayed by either the loin eye muscle or the lean mass of the carcass was well within the errors of measurement. Symmetry rather than asymmetry would seem to be the rule. On this basis it would be most plausible to conclude that consistent directional right-left differences were caused by operator biases in measurement and cutting rather than by real differences between the right and left halves of the pigs.

TABLE VI

ANALYSIS OF VARIANCE OF THE RIGHT-LEFT DIFFERENCES OF LOIN EYE AREAS AT FOUR LOCATIONS[1]

Source	D.F.	S.S.	M.S.	E.M.S.
Total	167	4.8916		
Between Pigs	41	1.1258	.0274	$\sigma^2 + 4\sigma^2$
Within Pigs	126	3.7658	.0299	σ^2

Intraclass Correlation = -.02

[1]Locations: 6th-7th thoracic vertebrae, 10th-11th thoracic vertebrae, 14th thoracic vertebra, 3rd lumbar vertebra.

TABLE VII

ANALYSIS OF VARIANCE OF THE RIGHT-LEFT DIFFERENCES OF THE LEAN OF THE HAM, THE MIDDLE, AND THE SHOULDER

Source	D.F	S.S.	M.S.	E.M.S.
Total	125	14.28		
Between Pigs	41	3.89	.095	$\sigma^2 + 3\sigma^2$
Within Pigs	84	10.39	.124	σ^2

Intraclass Correlation = -.08

The magnitude of the errors of measurement and the reliability of the various measurements were computed on an intraseasonal basis using an approach similar to that of Lasley and Kline (1957). The pertinent statistics are given in Tables VIII to XII. The details of the method are shown in Appendix A. The measuring or cutting error variance was taken to be the variance between sides within pigs. It is regarded as a measure of operator error (inability to measure the right and left side the same) and of operator bias (consistent directional difference in side to side measurements). In a statistical sense operator error stemmed from the pig x side component and operator bias from the side component. The coefficient of variation was obtained by dividing the standard deviation of the measuring error by the overall right-left mean and multiplying by 100. Estimates of repeatability (intraclass correlation) were obtained from the measuring error variance and the between pig component of variance. The standard deviation of the difference between the right-left measurements was computed from the pig x side component. As such, this standard deviation is free of operator bias and stems solely from operator error.

On the supposition that pigs differing moderately in size can be cut and measured with about equal accuracy, the standard deviation of the differences, the measuring error variances, and the coefficients of variation are absolute measures of error which should afford comparisons from one study to another. On the other hand the repeatability estimates indicate the ability of the measure to discriminate among pigs. These estimates are a function of both the error of measurement and of the magnitude of the differences among pigs; as such they are population statistics applicable only to the population under consideration.

Reliable separations were made of fat and of lean in the half carcass, the middle, and the ham, and of lean in the shoulder; repeatabilities exceeded .86 (Table VIII). These traits could have been satisfactorily determined from one half of the carcass. The lean of the carcass was split more reliably than was fat or bone. Due to the small total variance and the small amount of bone, the splitting errors of bone were relatively greater than those of fat and lean. This is apparent from the repeatabilities of .98 for lean, .94 for fat, and .42 for bone between the right and left halves of the carcasses.

The greatest splitting errors were made in the shoulder and the least in the ham. In addition the shoulder displayed the greatest separation errors in fat, lean, and bone. To some extent this would be a natural consequence of the less accurate split. With the exception of bone, the middle and the ham were separated with about equal reliability. The repeatability of bone was low in both the shoulder ($r = .15$) and the middle ($r = .52$) but was higher in the ham ($r = .78$). There was a tendency to cut the left side of the carcass heavier. The bias was primarily in the middle region. The cutting error variance of 1.594 for the half carcass compares favorably with the value of 2.415 obtained by Lasley and Kline (1957). The pig components of variance for fat and lean were greatest in the middle and least in the shoulder. The greatest variance in the middle can be attributed to the heaviest weight of the middle section. The fact that the ham possessed a larger pig component than the shoulder may be indicative of larger real differences among pigs in the region of the ham compared to the shoulder. The differences noted were not large enough to be detected as statistically significant.

TABLE VIII

MEANS, CUTTING ERRORS, AND REPEATABILITIES OF THE HALF CARCASS, SHOULDER, MIDDLE, AND HAM

Trait	Mean Right	Mean Left	Mean Differ.	St. Dev. of the Differ.	Cutting Error Variance	Coefficient of Variation	Left-Right Repeat-ability	Variance due to Pigs
Weight (Lbs.)								
Half Carcass	69.47	70.11	-.64*	1.57	1.594	1.81	.74	4.593
Shoulder	18.73	18.82	-.09	1.37	.925	5.12	.28	.357
Middle	32.10	32.72	-.62*	.67	.482	2.14	.80	1.896
Ham	18.65	18.57	.08	.46	.104	1.74	.86	.641
Fat - Half Carcass	32.05	32.41	-.36*	.90	.501	2.20	.94	8.449
Shoulder	7.38	7.45	-.07	.71	.258	6.85	.49	.246
Middle	17.77	18.20	-.44*	.60	.281	2.95	.93	3.725
Ham	6.90	6.75	.15*	.31	.060	3.49	.89	.448
Lean - Half Carcass	28.62	28.64	-.02	.54	.139	1.30	.98	6.623
Shoulder	8.31	8.34	-.03	.42	.088	3.56	.87	.585
Middle	11.21	11.24	-.03	.31	.047	1.93	.96	1.147
Ham	9.10	9.06	.04	.28	.035	2.06	.96	.847
Bone - Half Carcass	8.30	8.28	.02	.54	.510	8.67	.42	.363
Shoulder	2.94	2.86	.08	.37	.070	9.09	.15	.012
Middle	2.73	2.78	-.05*	.33	.066	9.32	.52	.073
Ham	2.63	2.64	-.02	.10	.006	2.94	.78	.021
Percent Lean								
Half Carcass	41.16	40.82	.34	.99	.587	1.87	.95	10.853
Shoulder	44.37	44.31	.05	2.18	2.269	3.40	.74	6.401
Middle	34.96	34.42	.53*	1.14	.891	2.72	.94	13.463
Ham	48.70	48.67	.03	1.20	.696	2.40	.94	11.117

*Denotes statistical significance at P = .05.

Particularly high repeatabilities were obtained for the percentage of separable lean in the half carcass, the middle, and the ham (r = .95, .94, and .94 respectively). The value for the shoulder was somewhat lower (r = .74).

Carcass length, carcass back fat, and specific gravity of the half carcass, the shoulder, the middle, and the ham exhibited small measuring error variances and high repeatabilities (Table IX). These traits could have been measured on one side of the carcass without undue loss in precision. A high repeatability was obtained for live probes; however, this was to be expected because of the manner in which probes were taken. (See Materials and Methods.) The value of .011 for the measuring error variance of length is similar to that reported by Lasley and Kline (1957). As would be expected, on the basis of splitting errors, the specific gravity of the shoulder displayed the greatest error and that of the ham the least. Nevertheless the repeatability estimate of .77 for right-left specific gravity of the shoulder would indicate that, even where specific gravity was least reliable, it possessed reasonable ability to distinguish pigs.

If the separable lean from different pigs had been a homogeneous product, the repeatabilities of its chemical constituents would have been zero. From Table IX it is apparent that this was not so. A substantial pig component still existed for fat (r = .87) and water (r = .82). Ash differences were well standardized (r = .27) and protein differences were not large (r = .47). The pig component for chemical fat may have been caused by marbling variation; however, a tendency to remove less external fat from fatter pigs could also have been a factor. The latter may have been important in removing the abdominal muscles because

TABLE IX

MEANS, MEASUREMENT ERRORS, AND REPEATABILITIES OF CARCASS LENGTH, LIVE PROBES, CARCASS BACK FAT, SPECIFIC GRAVITY, AND THE CHEMICAL COMPOSITION OF SEPARABLE LEAN

Trait	Mean			St. Dev. of the Differ.	Measuring Error Variance	Coefficient of Variation	Left-Right Repeat-ability	Variance due to Pigs
	Right	Left	Differ.					
Length (In.)	29.70	29.75	-.05	.14	.011	.35	.97	.340
Live Probe (In.)								
Shoulder	1.80	1.80	.00	.07	.003	2.84	.91	.025
Loin	1.36	1.36	.01	.07	.003	2.84	.87	.017
Carcass Back Fat (In.)								
First Rib	1.81	1.80	.01	.11	.006	4.35	.84	.032
Seventh Rib	1.45	1.44	.01	.08	.003	3.99	.92	.037
Last Rib	1.24	1.23	.01	.10	.006	6.38	.78	.022
Last Lumbar	1.39	1.39	.00	.07	.003	3.67	.94	.042
Specific Gravity								
Carcass	1.039	1.038	.001*	.003	4.7×10^{-6}	.19	.91	46.8×10^{-6}
Shoulder	1.049	1.048	.002*	.005	11.9×10^{-6}	.33	.77	40.0×10^{-6}
Middle	1.024	1.024	.001*	.003	8.8×10^{-6}	.29	.86	55.0×10^{-6}
Ham	1.054	1.054	.000	.002	1.4×10^{-6}	.11	.96	39.1×10^{-6}
Separable Lean (%)								
Water	68.41	68.53	-.12	.88	.374	.89	.82	1.712
Ash	1.04	1.02	.01	.08	.004	5.89	.27	.001
Fat	10.72	10.78	-.06	.88	.394	5.84	.87	2.562
Protein	19.32	19.56	-.24	.64	.266	2.44	.47	.196

*Denotes statistical significance at P = .05.

in fatter pigs these muscles were narrower and more difficult to dissect. The abdominal muscles were, however, a small part of the total lean and should not have created a large bias. The fact that fatter pigs tended to yield more chemical fat in the separable lean is indicated by a correlation of .50 between the weight of carcass fat and the percent of chemical fat in the lean. Since fatter pigs are generally heavier marbled, the extent to which this correlation was caused by marbling variation or by separation bias is fully confounded.

The areas of fat, the areas of muscle components, and the percentages of lean generally were obtained more accurately in the cross sections in the mid-region (CS6T to CS2S) compared with those at either extremity (Tables X-XII). For the total areas, repeatabilities in the mid-region were above .74 compared with .59 at the second-third thoracic vertebrae, .55 through the center of the ham, and .25 through the shank of the ham.

In each cross section, except the one through the shank of the ham, the area of fat showed more measuring error variance than did the area of lean. However, with the exception of the cross sections at the second-third thoracic vertebrae and through the shank of the ham, the pig component of variance of fat area was sufficiently greater than the pig component of variance of lean area so as to make fat area measurements generally more repeatable than lean area measurements. Also fat area tended to be more highly repeatable than total area. Values above .85 were obtained for cross sections at the sixth-seventh thoracic vertebrae through to the second-third sacral vertebrae. The value at the second-third thoracic vertebrae was .78 and those at the center and the shank of the ham were .75 and .58 respectively.

TABLE X

MEANS, MEASUREMENT ERRORS, AND REPEATABILITIES FOR THE TOTAL CROSS SECTIONAL AREA AND THE PERCENT LEAN IN THE CROSS SECTION FOR EACH OF EIGHT CROSS SECTIONS

Trait and Location[1]	Mean			St. Dev. of the Differ.	Measuring Error Variance	Coefficient of Variation	Left-Right Repeat-ability	Variance due to Pigs
	Right	Left	Differ.					
Total Area (Sq. In.)								
CS2T	41.89	41.32	.57	2.12	2.387	3.71	.59	3.401
CS6T	35.19	35.34	-.15	1.31	.890	2.68	.87	5.744
CS10T	31.44	31.53	-.08	1.23	.738	2.73	.91	7.784
CS14T	27.97	28.49	-.52	1.24	.867	3.30	.86	5.228
CS3L	30.94	31.56	-.62	1.21	1.011	3.22	.78	3.521
CS2S	39.78	40.00	-.22	1.24	.773	2.20	.75	2.313
CSCH	47.77	46.85	.91*	1.96	2.253	3.17	.55	2.773
CSSH	29.76	30.98	-1.22*	2.90	4.743	7.17	.25	1.546
Percent Lean								
CS2T	38.88	38.47	.42	2.42	3.106	4.56	.86	19.338
CS6T	32.09	29.92	2.16*	2.33	5.659	7.67	.73	15.439
CS10T	24.39	23.36	1.02*	1.74	1.974	5.88	.89	15.330
CS14T	27.75	27.60	.14	2.20	2.321	5.50	.86	14.912
CS3L	35.85	35.64	.21	2.01	2.144	4.10	.90	19.262
CS2S	41.19	40.69	.50	1.99	2.018	3.47	.89	16.103
CSCH	70.17	69.99	.19	2.93	4.113	2.89	.81	17.974
CSSH	55.40	55.38	.02	2.91	4.080	3.65	.87	27.078
Percent Loin Eye								
CS10T	11.57	11.40	.16	.55	.162	3.50	.96	3.542

[1]See Table IV for location and cross section code.
*Denotes statistical significance at P = .05.

TABLE XI

MEANS, MEASUREMENT ERRORS, AND REPEATABILITIES FOR THE AREAS OF FAT AND LEAN IN EACH OF EIGHT CROSS SECTIONS

Trait and Location[1]	Mean Right	Mean Left	Mean Differ.	St. Dev. of the Differ.	Measuring Error Variance	Coefficient of Variation	Left-Right Repeat-ability	Variance due to Pigs
Fat Area (Sq. In.)								
CS2T	25.65	25.45	.20	1.80	1.705	5.11	.78	5.857
CS6T	24.03	24.88	-.84*	1.16	1.283	4.64	.86	7.720
CS10T	23.88	24.21	-.33	1.09	.630	3.30	.94	9.733
CS14T	20.28	20.71	-.43	1.11	.678	4.02	.91	6.752
CS3L	19.92	20.39	-.47	1.12	.850	4.57	.87	5.579
CS2S	23.44	23.76	-.32	1.14	.674	3.48	.87	4.584
CSCH	14.20	14.06	.14	1.61	1.237	7.87	.75	3.693
CSSH	13.22	13.74	-.53	1.51	1.243	8.27	.58	1.708
Lean Area (Sq. In.)								
CS2T	16.12	15.76	.36	1.19	.776	5.47	.80	3.058
CS6T	11.21	10.47	.74*	.92	.746	7.96	.61	1.167
CS10T	7.57	7.33	.24	.62	.227	6.41	.79	.865
CS14T	7.69	7.79	-.10	.65	.207	1.97	.71	.515
CS3L	11.04	11.19	-.15	.70	.244	4.45	.82	1.082
CS2S	16.36	16.26	.10	.89	.388	3.95	.85	2.254
CSCH	33.54	32.83	.70*	1.46	1.262	3.38	.84	6.904
CSSH	16.54	17.13	-.59	1.85	1.858	8.07	.73	5.174

[1]See Table IV for location and cross section code.
*Denotes statistical significance at P = .05.

TABLE XII

MEANS, MEASUREMENT ERRORS, AND REPEATABILITIES FOR THE AREAS IN SQUARE INCHES OF THE MUSCLE COMPONENTS OF EACH OF EIGHT CROSS SECTIONS

Location and Muscle Group[1]	Mean			St. Dev. of the Differ.	Measuring Error Variance	Coefficient of Variation	Left-Right Repeat-ability	Variance due to Pigs
	Right	Left	Differ.					
CS2T								
Muscle Group 1	1.20	1.17	.04	.17	.015	10.33	.58	.021
2	6.67	6.59	.09	.71	.242	7.42	.67	.501
3	8.26	8.00	.26*	.67	.256	6.22	.80	.990
CS6T								
Muscle Group 1	2.63	2.56	.04	.14	.013	4.36	.91	.129
2	2.25	2.21	.04	.36	.063	11.25	.48	.057
3	4.86	4.45	.41*	.55	.259	10.94	.33	.127
4	1.47	1.25	.23*	.36	.091	22.19	.56	.114
CS10T								
Muscle Group 1	3.60	3.55	.04	.16	.013	3.14	.94	.206
2	.35	.33	.03	.21	.023	45.00	-.10	.000
3	2.80	2.58	.22	.52	.155	14.61	.48	.140
4	.81	.82	-.01	.22	.023	18.68	.61	.037
CS14T								
Muscle Group 1	3.72	3.75	-.03	.16	.015	3.26	.93	.185
2	.53	.59	-.05	.21	.023	28.20	.13	.002
3	2.12	2.11	.11	.52	.128	16.94	.34	.065
4	1.32	1.34	-.03	.16	.014	8.80	.78	.049

Table XII (Continued)

Location and Muscle Group[1]	Mean Right	Mean Left	Mean Differ.	St. Dev. of the Differ.	Measuring Error Variance	Coefficient of Variation	Left-Right Repeat-ability	Variance due to Pigs
CS3L								
Muscle Group 1	3.85	3.92	-.06	.18	.018	3.48	.91	.193
2	2.39	2.49	-.10	.34	.063	10.27	.52	.068
3	2.53	2.59	-.06	.29	.042	7.99	.64	.073
4	2.27	2.20	-.07	.28	.041	9.04	.67	.084
CS2S								
Muscle Group 1	9.13	9.49	-.36*	.59	.240	5.26	.75	.714
2	4.90	4.83	.07	.53	.138	7.65	.75	.409
3	2.32	1.94	.38*	.41	.157	18.62	.29	.066
CSCH								
Muscle Group 1	7.49	6.26	1.23*	1.54	1.892	20.00	.25	.619
2	15.15	15.29	.14	1.01	.497	4.63	.76	1.600
3	3.92	3.93	-.02	.58	.162	10.27	.62	.267
4	6.98	7.32	-.34*	.63	.246	6.94	.63	.425
CSSH								
Muscle Group 1	4.16	4.04	.12	.71	.248	12.02	.41	.171
2	3.72	3.97	-.25	.80	.334	15.04	.38	.209
3	2.26	2.37	.11	.25	.042	8.80	.73	.110
4	6.40	6.76	-.36	1.36	.966	14.94	.57	1.281

[1]See Table IV for location and muscle group code.
*Denotes statistical significance at P = .05.

While lean areas and percent lean were measured less accurately at the second-third thoracic vertebrae and in the ham, these cross sections contained greater pig components of variance for these two traits. Hence repeatabilities of lean areas (Table XI) and of percent lean (Table X) were not adversely affected to the same extent as were repeatabilities of total areas and fat areas. Repeatabilities of lean areas were above .78 in the cross sections at the second-third thoracic vertebrae, the tenth-eleventh thoracic vertebrae, the third lumbar vertebra, the second-third sacral vertebrae, and through the center of the ham. In cross sections at the fourteenth thoracic vertebra and the shank of the ham, values were .71 and .73 respectively. In the case of percent lean, all repeatabilities were above .80 except in the cross section at the sixth-seventh thoracic vertebrae. The cross section at the sixth-seventh thoracic vertebrae gave the lowest repeatability for both lean area and percent lean (.61 and .73 respectively). These low values appear to be the result of a large measuring error variance which stemmed from a bias whereby the right half averaged .84 square inch less fat and .74 square inch more lean. The cause of this bias is not apparent.

The _longissimus dorsi_ was measured with low error in the four cross sections from the sixth-seventh thoracic vertebrae through to the third lumbar vertebra (Table XII, Muscle Group 1). All repeatabilities were in excess of .90. These data certainly substantiate the accepted practice of restricting measurements of the _longissimus dorsi_ to one side of the carcass. The other muscle components of these four cross sections showed considerably more error variance and correspondingly lower repeatabilities. Particularly unreliable were the areas of the small muscles around the _longissimus dorsi_ (Muscle Group 2). The measuring error variances of .013 and .015 for the longissimus dorsi at the tenth-eleventh vertebrae and at the fourteenth thoracic vertebra respectively are appreciably less than the respective values of .032 and .027 reported by Lasley and Kline (1957).

The muscle components of the cross section at the sixth-seventh thoracic vertebrae indicated that the bias in total lean, noted previously, stemmed primarily from Muscle Groups 2 and 3. Distinct biases also existed in Muscle group 3, at the second-third thoracic vertebrae; Muscle Groups 1 and 3, at the second-third sacral vertebrae; and Muscle Groups 1 and 4, at the center of the ham.

In the cross sections not dominated by the longissimus dorsi, the repeatabilities of specific muscle groups tended to be lower than the repeatabilities of total lean areas (Table XI). This would indicate that a certain amount of cancelling of errors occurred when the individual components were combined into a single total.

In general, with the exception of the longissimus dorsi, these data indicate that to reliably estimate the area of a muscle, it should be measured on both sides of the carcass.

RESULTS AND DISCUSSION

Intraseason simple and multiple regression analyses were used to investigate the ability of various indices to explain the variation in percent lean and weight of lean in the carcass. The elements of each index were composed of the sum of the corresponding right and left measurements of the pig. The pertinent statistics are given in Table XIII.

The live probe accounted for .48 and .33 of the variance in percent lean and weight of lean respectively. This was more variance than was explained by carcass back fat thickness (r^2 = .36 and .21 respectively). Carcass length showed a low relationship to both percent lean and weight of lean (r^2 = .06 and .08). Moreover the joint value of length and carcass back fat was the same as that of back fat. The low percent of variation explained by length is in accord with other studies (Price *et al.*, 1957; Holland and Hazel, 1958; Zobrisky *et al.*, 1959).

The superiority of the live probe, noted here, over carcass back fat measurements is well, though not consistently, supported in the literature. The relative amount of variation partitioned by each of these two indices is similar to the average which they have partitioned in percent lean cuts in other studies.

Loin eye area at the tenth rib[1] accounted for .43 and .57 of the variance in percent lean and weight of lean respectively, and joint consideration of loin eye area and carcass back fat explained .70 of the

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[1]Synonymous with the cross section at the 10th-11th thoracic vertebrae (CS10T).

TABLE XIII

THE RELIABILITY OF VARIOUS INDICES BASED ON COMBINED RIGHT AND LEFT MEASUREMENTS FOR THE ESTIMATION OF PERCENT LEAN AND WEIGHT OF LEAN IN THE CARCASS AS INDICATED BY THE VARIANCE EXPLAINED, STANDARD ERRORS, AND PREDICTION ERRORS FROM INTRASEASON MULTIPLE OR SIMPLE REGRESSION ANALYSES

Index[1]	Percent Lean			Weight of Lean		
	R^2 or r^2	S.E.	P.E.	R^2 or r^2	S.E.	P.E.
Live Probe	.48	.39	2.54	.33	.68	4.46
Carcass Length	.06	.52	3.42	.08	.80	5.24
Back Fat Thickness	.36	.43	2.82	.21	.74	4.83
Loin Eye Area--10th Rib	.43	.41	2.67	.57	.54	3.58
Length and Back Fat	.36	.43	2.82	.22	.74	4.83
Loin Eye Area & Back Fat	.70	.30	1.93	.70	.45	3.01
Specific Gravity (S.G.)						
Ham	.69	.30	1.97	.52	.57	3.76
Carcass	.58	.35	2.27	.45	.62	4.06
Loin Eye Area & S.G. (Ham)	.79	.25	1.61	.76	.41	2.69
Loin Eye Area, S.G. (Ham), and Back Fat	.81	.23	1.54	.76	.40	2.64
Components of the Ham						
Weight of Lean	.82	.23	1.52	.90	.26	1.70
Weights of Lean and Fat	.92	.15	1.00	.91	.24	1.60
Areas of Fat and Lean						
CS2T	.79	.26	1.62	.69	.46	3.04
CS6T	.81	.23	1.52	.78	.39	2.55
CS10T	.85	.21	1.37	.77	.40	2.65
CS14T	.77	.26	1.68	.58	.53	3.49
CS3L	.89	.18	1.19	.80	.37	2.41
CS2S	.77	.26	1.68	.72	.44	2.88
CSCH	.81	.23	1.54	.77	.40	2.61
CSSH	.72	.28	1.86	.55	.56	3.65
Areas of Fat and Muscle Groups in CS3L	.91	.17	1.06	.83	.35	2.24

[1]Regression coefficients for the multiple regression indices are given in Appendix B (Tables XXV and XXVI).

variance in each of these two dependent variables. The ability of loin eye area to partition 14 percent more variation in weight of lean than it did in percent lean revealed, as would be expected, that this index measured the absolute contribution of lean better than it did the relative contribution.

The 70 percent of the variance in either percent lean or weight of lean partitioned jointly by carcass back fat thickness and loin eye area was substantially more than that partitioned by the live probe (R^2 of .48 and .33 for percent lean and weight of lean respectively). This indicated that while the live probe did have certain discriminating ability in this study routine carcass measurements better described the merit of the pigs. This is not well supported in the literature. Holland and Hazel (1958) obtained data which indicated that the live probe was equivalent to routine carcass measurements in estimating leanness when percent lean cuts was the criterion of net merit. In a further trial, Hazel and Kline (1959) obtained correlations of live back fat measurements with percent lean cuts of the order of .85 to .90 indicating the live probe could effectively distinguish leanness. For the most part, these two studies from Iowa have cast live fat measurements in a better light than have studies elsewhere, and certainly in a better light than has this trial.

Specific gravity of the carcass explained .58 and .45 of the variance in percent lean and weight of lean respectively which was somewhat less variance than was explained by specific gravity of the ham ($r^2 = .69$ and .52 respectively). The ability of specific gravity to explain relatively more variation in percent lean than in weight of lean was to be expected because specific gravity is determined by the proportional parts of fat and lean rather than by the absolute amounts. As a single index, specific gravity of either the carcass or the ham was superior to either carcass back fat or loin eye area in explaining the variation in percent lean. This is in complete accord with other results (Brown et al., 1951; Pearson et al., 1956a; Whiteman and Whatley, 1953). It was not superior, however, to loin eye area in explaining the variation in weight of lean, reflecting again that the former can be expected to better estimate the proportion of lean and the latter the absolute quantity of lean.

Joint consideration of specific gravity and loin eye area gave R^2 values of .79 and .76 respectively with percent lean and weight of lean. This was an explanation of 10 and 24 percent more variation than was explained by specific gravity of the ham alone, and is greater than the increase of four percent obtained by Whiteman et al., (1953) when specific gravity of the carcass was jointly considered with loin eye area as an estimator of percent lean cuts. The consideration of carcass back fat, after loin eye area and specific gravity of the ham had been considered, did not result in the partitioning of much more variance in either percent lean or weight of lean (R^2 of .81 and .76 compared to .79 and .76 respectively).

Joint consideration of the weights of fat and lean in the ham explained .92 and .91 of the variance in percent lean and weight of lean respectively. When only weight of lean was considered, r^2 values of .82 and .90 were obtained. The lower value of .82, while appreciable, reflected that percent lean was better appraised by jointly considering both fat and lean measurements. The high portion of variance partitioned here clearly indicated that the fat and lean components of the ham admirably reflected the fat and lean composition of the carcass. This is in complete accord with Hazel and Kline (1959), Pearson et al., (1958), Smith et al. (1957), and Whiteman and Whatley (1953) who obtained correlations of .96, .90, .89, and .89 respectively between percent trimmed ham and percent lean cuts, and whose data indicate this trait to be more closely allied with percent lean cuts than any conventional index.

The variance in percent lean explained by the areas of fat and lean in the various cross sectional tracings ranged from .72 to .89. The cross section most poorly related to percent lean (CSSH) actually partitioned slightly more variance than was partitioned jointly by the conventional measurements of loin eye area at the tenth rib and carcass back fat thickness (R^2 of .72 vs. .70).

Resolution of the area of lean of the cross section at the third lumbar vertebra into specific muscle groups raised the variance explained by this cross section from .89 to .91 and revealed that the important contributing muscles were the longissimus dorsi (Muscle Group 1), and the cutaneous muscle and the rectus abdominis (Muscle Group 4)(Table XIV). It was noted that the loin eye area was .15 square inch larger and the variance in percent lean partitioned by it ten percent greater at this point than at any other point examined (Tables XII and XV).

The variation in total lean explained by cross sectional areas of fat and lean was not as great as that explained in percent lean. Nevertheless seven of the eight cross sections were superior to either loin eye area at the tenth rib or back fat thickness, and five explained more variance than was explained jointly by loin eye area and back fat thickness. As was the case with percent lean, the cross section at the third lumbar vertebra was most closely associated with weight of lean, and resolution of its area of lean into muscle groups again revealed that the _longissimus dorsi_ (Muscle Group 1), and the cutaneous muscle and the _rectus abdominis_ (Muscle Group 4) were the major contributing muscle components (Table XIV).

TABLE XIV

THE VARIANCE IN PERCENT LEAN AND WEIGHT OF LEAN IN THE CARCASS PARTITIONED BY THE AREAS OF FAT AND MUSCLE GROUPS IN A CROSS SECTION AT THE THIRD LUMBAR VERTEBRA

		Percent Lean		Weight of Lean	
Source	DF	SS	MS	SS	MS
Total	40	450.41		1070.70	
Fat Area (F.A.)	1	343.33	343.33	536.57	536.57
Gr. 1/F.A.	1	45.92	45.92	292.76	292.76
Gr. 4/Gr. 1 & F.A.	1	18.58	18.58*	28.27	28.27*
Error (a)	37	42.58	1.15	213.10	5.76
Gr. 2/Gr. 4, Gr. 1 & F.A.	1	2.05	2.05	19.98	19.98
Error (b)	36	40.53	1.13	193.12	5.36
Gr. 3/Gr. 2, Gr. 4, Gr. 1 & F.A.	1	.21	.21	13.22	13.22
Error (c)	35	40.32	1.15	179.90	5.14

*Significant at P = .05.

The cross section through the shank of the ham explained the least variance in the two dependent variables (R^2 = .72 for percent lean and .55 for weight of lean). Undoubtedly this was due in part to a failure to obtain the cross sectional components as accurately at this point as at others (Table XI).

Of special interest was the cross section at the 14th thoracic vertebra. While it was measured with good accuracy, it ranked seventh in its relationship to percent lean and weight of lean. These relatively low relationships might be attributed jointly to its small area of total

TABLE XV

THE INTRASEASON VARIANCE EXPLAINED IN PERCENT LEAN AND WEIGHT OF LEAN IN THE CARCASS BY THE AREAS OF MUSCLE CROSS SECTIONS AT EIGHT POINTS OF THE CARCASS WHERE AREAS ARE BASED ON COMBINED RIGHT AND LEFT MEASUREMENTS

Muscle Cross Section	Percent Lean r^2	Weight of Lean r^2
CS2T		
Muscle Group 1 (Loin Eye)	.41	.29
2	.42	.44
3	.53	.54
CS6T		
Muscle Group 1 (Loin Eye)	.54	.44
2	.36	.22
3	.41	.39
4	.36	.37
CS10T		
Muscle Group 1 (Loin Eye)	.57	.43
2	.05	.02
3	.51	.44
4	.19	.16
CS14T		
Muscle Group 1 (Loin Eye)	.56	.48
2	.03	.03
3	.02	.02
4	.25	.26
CS3L		
Muscle Group 1 (Loin Eye)	.67	.55
2	.34	.28
3	.33	.24
4	.44	.46
CS2S		
Muscle Group 1	.43	.43
2	.54	.37
3	.24	.26
CSCH		
Muscle Group 1	.20	.15
2	.44	.48
3	.16	.09
4	.61	.62
CSSH		
Muscle Group 1	.16	.18
2	.35	.40
3	.43	.45
4	.35	.48

lean (average of 7.45 square inches per side), to a smaller relationship between its muscle components (other than loin eye area) and percent lean or weight of lean in the carcass, and finally to an exceptionally small component of variance due to lean (Tables XI and XV). For the most part, these data indicated that this cross section offered the least scope in detecting differences in lean content when any component other than loin eye area was considered. Contrasted to this was the cross section through the loin region (CS3L) where both side to side repeatability and the pig component of variance for lean compared favorably with other points and where loin eye area demonstrated its closest relation to merit. Finally, there were no ribs at this point of the carcass and hence the ease with which area components could be evaluated was enhanced.

A statistical appraisal of the value of the various indices in comparison with one another was provided by setting 95 percent confidence intervals on r^2 and R^2 (Table XVI). Confidence intervals were set by the conventional Z transformation.

Such a procedure is reasonably reliable for r^2 but is not strictly valid for R^2. Its use in the case of R^2 has a degree of logic since R can be regarded as a simple correlation between the actual and estimated values. Further, the upper limits provided on R^2 are essentially the same as those from graphs prepared by Ezekiel (1941). The difference between two indices can be considered statistically significant at the .05 level if their confidence intervals do not overlap. This procedure is not rigorous and exacting statistical methodology. The intervals provided are at best approximations but the method is as appropriate as any available. In this study the intervals are wide and the variances partitioned by the various indices, in general, do not differ significantly from one another.

TABLE XVI

CONFIDENCE INTERVALS ON R^2 AND r^2

Index	Percent Lean: R^2 or r^2	Percent Lean: 95% C.I.	Weight of Lean: R^2 or r^2	Weight of Lean: 95% C.I.
Live Probe	.48	.23 to .69	.33	.10 to .56
Carcass Length	.06	.00 to .27	.08	.00 to .28
Back Fat Thickness	.36	.12 to .61	.21	.04 to .49
Loin Eye Area--10th Rib	.43	.16 to .63	.57	.33 to .75
Length and Back Fat	.36	.12 to .61	.22	.04 to .49
Loin Eye Area and Back Fat	.70	.52 to .83	.70	.52 to .83
Specific Gravity				
Ham	.69	.48 to .82	.52	.26 to .70
Carcass	.58	.34 to .75	.45	.20 to .67
Loin Eye Area & S.G. (Ham)	.79	.64 to .89	.76	.59 to .87
Loin Eye Area, S.G. (Ham), and Back Fat	.81	.67 to .90	.76	.59 to .87
Components of the Ham				
Weight of Lean	.82	.67 to .90	.90	.81 to .94
Weights of Lean and Fat	.92	.85 to .95	.91	.84 to .96
Areas of Fat and Lean				
CS2T	.79	.64 to .89	.69	.48 to .82
CS6T	.81	.67 to .90	.78	.64 to .88
CS10T	.85	.73 to .92	.77	.61 to .87
CS14T	.77	.61 to .88	.58	.34 to .75
CS3L	.89	.79 to .94	.80	.65 to .89
CS2S	.77	.61 to .87	.72	.53 to .85
CSCH	.81	.67 to .90	.77	.62 to .87
CSSH	.72	.53 to .84	.55	.31 to .73
Areas of Fat & Muscle Groups in CS3L	.91	.84 to .95	.83	.69 to .91

As a single measure of merit, the area of fat in any cross section was superior to carcass back fat thickness. When percent lean was the dependent variable, the superiority ranged from 14 to 40 percent. When weight of lean was the dependent variable, the superiority ranged from 12 to 39 percent (Table XVII). Thus, compared with conventional measurements, a substantial part of the advantage of cross sectional components in partitioning the variance in net merit stemmed from the fact that an area measurement of fat at a single point better indicated merit than did the total of a series of point measurements at several locations. Stated conversely, area measurements of fat measured the fat component of the carcass better than point measurements of fat and thereby enhanced appraisal of net merit.

TABLE XVII

THE VARIANCE PARTITIONED IN PERCENT LEAN AND WEIGHT OF LEAN IN THE CARCASS BY VARIOUS INDICES WHICH ARE MEASURES OF FATNESS AND WHICH ARE BASED ON COMBINED RIGHT AND LEFT MEASUREMENTS

Index	Percent Lean	Weight of Lean
Live Probe	.48	.33
Back Fat Thickness	.36	.21
Area of Fat		
CS2T	.58	.38
CS6T	.62	.37
CS10T	.72	.44
CS14T	.72	.44
CS3L	.76	.50
CS2S	.67	.44
CSCH	.72	.60
CSSH	.50	.33

In general, the advantages which this study has shown cross sectional area components to have as indices of merit over the conventional index of back fat thickness and loin eye area were not fully realized when measurements were restricted to one side of the carcass or where area components of cross sections in the mid-regions were restricted to loin eye area and fat area. This is shown in Table XVIII.

Consideration of measurements from only the right side of the carcass did not sharply reduce the variance explained by cross sectional components at all points. Where percent lean was the dependent variable, reduction varied from two percent for the cross section at the second sacral vertebra to eight percent for the cross section at the sixth thoracic vertebra. A slightly greater loss occurred when weight of lean was the dependent variable. This compared with back fat thickness and loin eye area at the tenth rib where a loss of four percent in the variance explained in each of the dependent variables occurred when measurements were restricted to the right side. These reductions in the variance explained simply reflected the repeatabilities of the measures involved. Where repeatability of each component of an index was of the order of .80 or more, the loss in variance explained by considering only the right side did not exceed six percent.

The area of fat and the area of the <u>longissimus</u> <u>dorsi</u> (loin eye) were examined jointly at three cross sections (CS10T, CS14T, CS3L) as indices of leanness (Table XVIII). The cross section at the 14th thoracic vertebra actually partitioned more variance when the lean component was restricted to loin eye area. This again reflected, as noted previously, that the lean component of this section, other than loin eye area, had little value as an indicator of merit.

TABLE XVIII

THE INTRASEASON VARIANCE IN PERCENT LEAN AND WEIGHT OF LEAN PARTITIONED BY VARIOUS INDICES COMPOSED OF COMBINED RIGHT AND LEFT MEASUREMENTS IN COMPARISON WITH RIGHT SIDE MEASUREMENTS ONLY

Trait	End Points: Percent Lean — Index: Areas or Weights of Fat & Lean — Right and Left		Index: % Areas or Weight of Lean — Right and Left		End Points: Weight of Lean — Index: Areas or Weights of Fat & Lean — Right and Left		Index: % Areas or Weight of Lean — Right and Left		Repeatability — Fat	Repeatability — Lean
	Right and Left	Right	Right and Left	Right	Right and Left	Right	Right and Left	Right	Fat	Lean
Areas of Fat and Lean										
CS2T	.79	.72	.79	.72	.69	.59	.66	.57	.78	.80
CS6T	.81	.73	.82	.72	.78	.66	.73	.61	.86	.61
CS10T	.85	.80	.85	.80	.77	.68	.78	.71	.94	.79
CS14T	.77	.75	.74	.69	.58	.54	.58	.55	.91	.71
CS3L	.89	.83	.88	.82	.80	.74	.76	.71	.87	.82
CS2S	.77	.75	.77	.76	.72	.69	.68	.64	.87	.85
CSCH	.81	.74	.80	.71	.77	.74	.72	.64	.75	.84
CSSH	.72	.68	.73	.69	.55	.47	.54	.48	.58	.73
Areas of Fat & Loin Eye										
CS10T	.78	.80	.76	.71	.68	.69	.71	.65	.94	.94
CS14T	.80	.79	.73	.72	.65	.66	.63	.65	.91	.93
CS3L	.86	.85	.76	.75	.76	.76	.70	.69	.87	.91
Components of the Ham										
Weight of Lean	.82	.79			.90	.86				
Weights of Fat & Lean	.92	.91	.93	.92	.91	.89	.90	.85	.89	.94
Back Fat and Loin Eye Area at 10th Rib	.70	.66			.70	.66			.95	.94

In the remaining two cross sections (CS10T and CS3L), consideration of loin eye area and fat area from right side measurements partitioned virtually the same amount of variance as was partitioned by the area of total lean and the area of fat. When both right and left measurements were combined, consideration of the area of total lean was advantageous. This indicated that the real merit of considering all cross sectional areas in these regions was contingent upon having both right and left measurements. When measurements were restricted to one side, consideration of only the more repeatable elements (loin eye area and fat area) provided about as much information as was to be had. This was not so when loin eye area and the area of total lean were expressed as percentages of the total area. Consideration of the area of total lean resulted in the partitioning of more variance but the increase was irratic, and at this point the data of Table XVIII failed to follow a consistent pattern.

Table XVIII also revealed that the expression of fat and lean components in multiple regression compared to the expression of lean as a percent of the total component explained essentially the same amount of variance. The choice of method of expression would seem to be arbitrary.

Throughout this discussion percent lean and weight of lean have been regarded as measures of net merit. Percent protein and weight of protein are also appropriate criteria of merit. In Table XIX a comparison has been made of the ability of each index considered to explain variation in each of the four measures of merit. The variance in percent lean or weight of lean was generally more fully partitioned than was the variance in percent protein or weight of protein (advantages up to eleven percent). This can be attributed to the fact that the separable lean was not a

TABLE XIX

THE INTRASEASON VARIANCE EXPLAINED (r^2 OR R^2) IN PERCENT LEAN, WEIGHT OF LEAN, PERCENT PROTEIN, AND WEIGHT OF PROTEIN IN THE CARCASS BY VARIOUS INDICES WHICH ARE BASED ON COMBINED RIGHT AND LEFT MEASUREMENTS

Index	Lean		Protein	
	Percent	Weight	Percent	Weight
Live Probe	.48	.33	.46	.35
Carcass Length	.06	.08	.03	.04
Back Fat Thickness	.36	.21	.32	.22
Loin Eye Area--10th Rib	.43	.57	.36	.52
Length and Back Fat	.36	.22	.33	.22
Loin Eye Area and Back Fat	.70	.70	.60	.67
Specific Gravity				
Ham	.58	.45	.65	.57
Carcass	.69	.52	.70	.60
Loin Eye Area & S.G. (Ham)	.79	.76	.77	.78
Loin Eye Area, S.G. (Ham), and Back Fat	.81	.76	.77	.78
Components of the Ham				
Weight of Lean	.82	.90	.71	.85
Weights of Lean and Fat	.92	.91	.85	.89
Areas of Fat and Lean				
CS2T	.79	.69	.77	.75
CS6T	.81	.78	.76	.76
CS10T	.85	.77	.78	.75
CS14T	.77	.58	.74	.62
CS3L	.89	.80	.80	.77
CS2S	.77	.72	.70	.70
CSCH	.81	.77	.78	.75
CSSH	.72	.55	.68	.58

homogeneous product but contained an appreciable fat difference, and to the fact that the indices, in reality, were measures of lean rather than of protein. Specific gravity provided an exception. It explained, depending on which criterion of merit was used, from one to twelve percent more variation in protein than it did in lean. This indicated that it had some sensitivity to protein content and might actually have been influenced by marbling differences. Overall, each index ranked the four criteria of merit in essentially the same order. Minor exceptions occurred because loin eye area and weight of lean in the ham better indicated weight of either lean or protein than they did percent and were therefore not in keeping with the pattern of the other indices.

SUMMARY AND CONCLUSIONS

Forty-two barrows were slaughtered to study the relationship between the lean content of the carcass and various measurements which may be used as indicators of leanness. It was unique from contemporary studies in that the separable lean of the carcass, rather than percent lean cuts, was the criterion of merit. It was conducted on a group of pigs homogeneous for sex, breed, and weight. To the extent that this homogeneity provided a group of pigs whose lean content did not vary widely, the relationships between various indices and lean content would be expected to be low. Conversely, in that all pigs were of the same general body conformation, each index would fit into a basic pattern and would be expected to show relatively higher relations with lean content. Because the intraseason variability among the pigs was not great and because the relationship between certain indices and merit were rather high, the latter undoubtedly occurred. Because of these high relationships, caution must be exercised in extending the results to different populations.

The ability of each index to explain variance in percent lean and to provide a useful index of merit was as follows: Carcass length was of little value in indicating leanness ($r^2 = .06$) and was of no value if carcass back fat was also considered. The live probe better indicated leanness ($r^2 = .48$) than did carcass back fat thickness ($r^2 = .36$) but was inferior to carcass back fat thickness and loin eye area at the tenth rib ($R^2 = .70$). Specific gravity of the ham was more closely associated with leanness than was specific gravity of the carcass (r^2 of .69 vs. .58).

Specific gravity of the ham mutually supplemented loin eye area in measuring leanness ($R^2 = .79$) but the relationship was only slightly enhanced by including back fat thickness ($R^2 = .81$). The lean and fat components of the ham were closely associated with merit ($R^2 = .92$).

The locations of eight cross sections and the abilities of their area components of fat and lean to explain variance in percent lean were the second-third thoracic vertebrae, $R^2 = .79$; the sixth-seventh thoracic vertebrae, $R^2 = .81$; the tenth-eleventh thoracic vertebrae, $R^2 = .85$; the fourteenth thoracic vertebra, $R^2 = .77$; the third lumbar vertebra, $R^2 = .89$; the second-third sacral vertebrae, $R^2 = .77$; the center of the ham, $R^2 = .81$; the shank of the ham, $R^2 = .72$. All indices, except loin eye area, were more closely related with percent lean than with weight of lean.

Interesting features were as follows:

(a) The routine measurements of loin eye area at the tenth rib and carcass back fat thickness were superior to the live probe as indicators of merit. The advantage was not significant at $P = .05$.

(b) Utilization of the area components of a cross section through the mid-loin improved carcass appraisal above that provided by routine measurements. The advantage approached significance at $P = .05$.

(c) Loin eye area at the third lumbar vertebra was more closely associated with leanness than was loin eye area at the sixth, tenth, or fourteenth vertebra.

(d) Areas of fat in full cross sectional tracings measured leanness somewhat better than did routine measurements of back fat thickness.

Where evaluation of carcasses more accurately than provided by loin eye area and back fat thickness is deemed necessary, these data indicate that full cross sectional tracings may have some utility.

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APPENDIX A

TABLE XX

INTRASEASON PHENOTYPIC CORRELATIONS AMONG TWENTY-THREE CARCASS TRAITS (DECIMALS OMITTED)

	A[1]	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
% Lean (B)	93																					
Protein																						
Weight (C)	96	93																				
Percent (D)	85	95	94																			
Live Probe (E)	-57	-69	-60	-68																		
Length (F)	27	24	21	16	-29																	
Back Fat (G)	-46	-60	-47	-57	70	-45																
Loin Eye (H)	75	66	72	60	-40	30	-13															
Lean in Ham																						
Percent (I)	91	97	90	91	-65	19	-58	68														
Weight (J)	95	90	92	84	-62	15	-54	72	91													
% Lean																						
CS2T (K)	81	89	94	88	-74	39	-69	52	85	78												
CS6T (L)	85	91	86	87	-69	27	-67	60	87	85	89											
CS10T (M)	88	92	87	86	-66	24	-53	76	89	86	83	90										
CS14T (N)	76	86	78	83	-57	07	-38	73	84	74	74	73	89									
CS3L (O)	87	94	87	89	-60	23	-45	73	92	81	82	84	91	91								
CS2S (P)	83	88	83	84	-70	26	-58	62	88	80	86	82	80	78	85							
CSCH (Q)	85	90	84	85	-74	33	-55	68	89	83	89	85	88	79	89	86						
CSSH (R)	73	85	76	84	-58	24	-53	59	86	76	75	82	84	82	87	80	85					
S.G.--Ham (S)	72	83	78	84	-59	24	-68	44	82	77	71	79	75	70	73	73	70	82				
% Loin Eye																						
CS6T (T)	79	83	80	80	-68	11	-53	80	84	82	78	81	85	84	82	78	83	77	71			
CS10T (U)	84	87	84	83	-67	17	-49	86	86	85	76	81	93	87	89	81	88	83	72	91		
CS14T (V)	80	86	82	83	-61	10	-44	77	85	82	73	77	87	89	89	76	86	86	73	85	94	
CS3L (W)	84	87	82	82	-59	15	-40	75	87	86	72	76	86	83	90	75	86	86	69	77	89	91

[1]A--Weight of Lean

TABLE XXI

INTRASEASON PHENOTYPIC CORRELATIONS AMONG TWENTY CARCASS TRAITS (DECIMALS OMITTED)

	A[1]	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
% Lean (B)	93																		
Protein																			
Weight (C)	96	93																	
Percent (D)	85	95	94																
Area of Lean																			
CS2T (E)	81	82	84	81															
CS6T (F)	86	78	83	72	85														
CS10T (G)	81	72	76	65	69	85													
CS14T (H)	65	62	65	60	56	62	84												
CS3L (I)	86	80	82	73	78	81	84	78											
CS2S (J)	84	79	82	74	76	80	69	62	80										
CSCH (K)	84	81	83	76	76	75	71	59	71	76									
CSSH (L)	71	79	73	76	62	62	54	45	60	68	98								
Area of Fat																			
CS2T (M)	-62	-77	-65	-75	-58	-46	-39	-29	-45	-57	-57	-60							
CS6T (N)	-61	-79	-67	-80	-59	-52	-37	-24	-41	-53	-62	-71	87						
CS10T (O)	-66	-84	-71	-83	-62	-53	-45	-34	-48	-56	-65	-75	83	91					
CS14T (P)	-66	-85	-70	-83	-60	-50	-50	-49	-57	-60	-64	-79	78	81	93				
CS3L (Q)	-71	-87	-74	-85	-65	-60	-54	-49	-59	-64	-67	-80	73	79	89	93			
CS2S (R)	-67	-82	-69	-79	-66	-53	-45	-38	-51	-67	-63	-68	83	78	83	84	84		
CSCH (S)	-77	-85	-77	-80	-80	-69	-60	-52	-72	-71	-72	-66	73	65	76	76	81	82	
CSSH (T)	-57	-71	-60	-69	-56	-56	-55	-53	-57	-53	-57	-56	60	58	65	68	71	68	78

[1]A--Weight of Lean

TABLE XXII

INTRASEASON PHENOTYPIC CORRELATIONS AMONG TWENTY CARCASS TRAITS (DECIMALS OMITTED)

	A[1]	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
% Lean (B)	93																		
Protein																			
Weight (C)	96	93																	
Percent (D)	85	95	94																
Area of Mus. Gr.																			
CS2T 1 (E)	64	54	63	51															
2 (F)	65	67	65	63	17														
3 (G)	73	74	78	76	47	58													
CS6T 1 (H)	73	66	70	60	62	54	58												
2 (I)	60	46	50	35	33	48	39	44											
3 (J)	64	63	65	60	34	63	68	46	58										
4 (K)	60	61	64	62	44	34	77	47	24	62									
CS10T 1 (L)	75	66	72	60	61	52	53	92	52	45	50								
2 (M)	22	12	18	08	23	13	05	19	43	15	24	26							
3 (N)	72	66	65	57	46	38	67	50	55	60	62	54	13						
4 (O)	43	40	45	41	36	23	36	47	21	28	53	56	33	41					
CS14T 1 (P)	75	69	76	68	62	52	58	76	43	42	54	85	08	56	50				
2 (Q)	17	18	12	11	05	27	-13	14	10	-08	-22	12	18	-05	03	10			
3 (R)	15	14	13	12	17	09	19	28	05	17	16	26	16	42	29	10	11		
4 (S)	50	51	53	53	43	17	40	53	18	27	56	59	18	51	84	63	-08	35	
% Lean in Middle (T)	91	99	91	94	52	62	73	63	45	57	61	64	12	67	39	67	18	15	52

[1] A--Weight of Lean

TABLE XXIII

INTRASEASON PHENOTYPIC CORRELATIONS AMONG TWENTY CARCASS TRAITS (DECIMALS OMITTED)

	A[1]	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
% Lean (B)	93																		
Protein																			
Weight (C)	96	93																	
Percent (D)	85	95	94																
Area of Mus. Gr.																			
CS3L 1 (E)	82	74	78	67															
2 (F)	58	53	58	52	48														
3 (G)	57	49	52	42	42	54													
4 (H)	67	68	65	63	61	38	47												
CS2S 1 (I)	66	66	69	66	54	55	39	60											
2 (J)	73	61	64	50	56	51	65	49	49										
3 (K)	49	52	50	50	53	02	12	43	26	25									
CSCH 1 (L)	45	39	42	36	55	09	21	91	28	27	36								
2 (M)	66	69	69	69	61	25	20	51	48	37	52	15							
3 (N)	38	29	29	19	24	34	43	44	25	45	08	-23	47						
4 (O)	78	78	78	76	68	38	52	53	65	58	48	39	60	08					
CSSH 1 (P)	40	43	42	43	46	00	25	32	34	21	24	36	42	05	48				
2 (Q)	59	64	60	61	56	42	25	40	51	42	51	52	38	07	55	01			
3 (R)	66	67	66	64	53	37	44	49	52	52	39	19	73	60	54	17	53		
4 (S)	59	69	61	67	57	30	18	35	46	36	46	44	61	14	65	30	75	57	
Wt. of Lean in Ham (T)	95	90	92	84	82	42	42	62	63	63	61	47	77	33	79	48	59	69	63

[1] A--Weight of Lean

TABLE XXIV

INTRASEASON PHENOTYPIC CORRELATIONS AMONG TWENTY CARCASS TRAITS (DECIMALS OMITTED)

	A[1]	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Chem. Anal.																			
% Fat (B)	34																		
% Prot. (C)	-27	-65																	
Weight																			
Carcass																			
Fat (D)	34	50	-36																
Lean (E)	41	-28	16	-70															
Bone (F)	42	09	-24	-43	63														
Shoulder																			
Fat (G)	39	57	-42	76	-41	-24													
Lean (H)	50	-21	02	-54	92	59	-32												
Bone (I)	40	11	-35	-26	47	83	-20	50											
Middle																			
Fat (J)	31	49	-34	97	-70	-42	61	-53	-23										
Lean (K)	38	-25	19	-72	97	61	-46	85	46	-69									
Bone (L)	37	10	-07	-43	57	84	-27	47	58	-38	61								
Ham																			
Fat (M)	18	28	-20	84	-65	-43	61	-53	-30	72	-71	-50							
Lean (N)	33	-33	24	-70	95	60	-37	79	38	-74	89	52	-57						
Bone (O)	26	14	-27	-31	49	53	-04	38	29	-35	48	45	-30	52					
Loin Eye Area																			
CS2T (P)	43	-12	13	-32	64	38	-15	62	30	-38	58	34	-20	63	31				
CS6T (Q)	39	-06	11	-50	73	61	-33	62	51	-47	74	62	-55	71	36	62			
CS10T (R)	45	-03	10	-46	75	59	-20	66	48	-46	75	57	-52	72	25	61	92		
CS14T (S)	33	-24	24	-53	75	43	-21	64	29	-54	72	51	-54	76	13	62	76	85	
CS3L (T)	42	-21	08	-52	82	53	-21	75	41	-53	77	52	-52	82	28	64	73	83	85

[1]A--Cold Carcass Weight

TABLE XXV

REGRESSION COEFFICIENTS FOR EQUATIONS PREDICTING THE WEIGHT OF LEAN IN THE CARCASS WHEN THE INDEPENDENT VARIABLES ARE BASED ON COMBINED RIGHT AND LEFT MEASUREMENTS

Index	Independent Variables									
	Length	Back Fat	Loin Eye Area	S.G. (Ham)	Area of Lean	Area of Fat	Muscle Group 1	2	3	4
Length and Back Fat	.37	-1.63								
Loin Eye Area and Back Fat		-1.43	3.97							
Loin Eye Area and S.G. (Ham)			3.03	.40						
Loin Eye Area, S.G. (Ham), and Back Fat		-.48	3.18	.32						
Weights of Fat and Lean in the Ham					2.47*	-.57*				
Areas of Fat and Lean										
CS2T					.95	-.22				
CS6T					1.56	-.20				
CS10T					1.69	-.31				
CS14T					1.41	-.44				
CS3L					1.60	-.33				
CS2S					1.19	-.22				
CSCH					.56	-.44				
CSSH					.62	-.43				
Areas of Fat and Muscle Groups in CS3L						-.32	2.65	.87	1.18	1.22

*Weight, not Area.

TABLE XXVI

REGRESSION COEFFICIENTS FOR EQUATIONS PREDICTING THE PERCENT LEAN IN THE CARCASS WHEN THE INDEPENDENT VARIABLES ARE BASED ON COMBINED RIGHT AND LEFT MEASUREMENTS

Index	Independent Variables									
							Muscle Group			
	Length	Back Fat	Loin Eye Area	S.G. (Ham)	Area of Lean	Area of Fat	1	2	3	4
Length and Back Fat	-.08	-1.54								
Loin Eye Area and Back Fat		-1.32	2.14							
Loin Eye Area and S.G. (Ham)			1.30	.36						
Loin Eye Area, S.G. (Ham), and Back Fat		-.50	1.46	.28						
Weights of Fat and Lean in the Ham					1.27*	-.93*				
Areas of Fat and Lean										
CS2T					.50	-.28				
CS6T					.69	-.31				
CS10T					.73	-.34				
CS14T					.58	-.45				
CS3L					.66	-.43				
CS2S					.47	-.40				
CSCH					.26	-.45				
CSSH					.40	-.42				
Areas of Fat and Muscle Groups in CS3L						-.42	.82	.36	.15	1.26

*Weight, not Area.

VITA

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