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Factors Affecting Quality in Mutton and Beef with Special Reference to the Proportions of Muscle, Fat, and Bone.*

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CONTENTS.

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BEEF.

GENERAL INTRODUCTION.

Never before in the history of the English meat eating public has there been such fastidious demand for meat as at the present day, a demand which has made it increasingly difficult for the producer, with the livestock at his command, to put before the consuming public exactly that article which they desire. The chief alterations in public taste have been the growing demand for smaller, lighter, and less fat joints. In bygone years heavy super-fatted animals were readily sold, but with smaller families, altered economic conditions and a higher standard of living, the public taste now, in lieu of the large fat joint, demands the lighter, leaner article.

To accentuate further the demand for small joints is the fact that the English public dislike cold meat, although during the summer months they will put up with it to some extent when salads are available. Changes in economic conditions have sharply influenced the taste for fat, that is, the improvement of machinery and mechanisation of labour has cut down the amount of hard work done by the labourer per unit of production, with the result that he now needs less calories to supply his day's energy expenditure than he formerly did; he loses the sharpness of his appetite and turns first and foremost against heavily fatted meats. This is well illustrated by the type of meat demanded in the coal-mining areas of the English Midlands where fat is still much relished and a rasher of bacon with a two-inch layer of fat is called for; this as compared with the London factory worker, the skilled labourer who expends comparatively little energy in the course of the day's work manipulating machinery, and who in consequence abhors more fat on his meat than is necessary for it to cook to advantage. (Fat should not be reduced beyond this point.) As regards the standard of living of the working classes, it has gone up considerably since the war, and with improved transport people are to-day able to enjoy the best from all parts of the world. Keen competition has set prices within the range of the labourer and mostly he wants only the best of those simpler foods necessary to his well-being.

The standard set by the "white heifer that travelled", an extremely fat and heavy beast, is no more, and instead of growing out and fattening his stock to great proportions, age being no limiting factor, the producer is now faced with the problem of reducing the selling weight of his animals while at the same time maintaining proportions of muscle, fat and bone in the carcase, which judged by the butchers' requirements can but remain an ideal; for the trade seeks a framework of bone so light on which to hang a vast quantity of meat, that from work done on growth their ideal would appear to be a biological impossibility. Tremendous strides have, however, been made in animal breeding to suit the present day demands and as examples can be quoted sheep like the Southdown and cattle like the Aberdeen Angus, which with the right management and feeding approach very closely to the butchers' ideal.

The drastic changes in public taste cannot be illustrated from the figures at our disposal, but some indication can be obtained from Tables I and II which, although covering the comparatively short space of thirteen years (1921-1933) point to the direction in which public taste has altered.

In 1840-1842 Southdown sheep 21 months old had a carcase weight of 122·6 lb., from 1893-1913 they averaged 90·8 lb., while killing fat changed from 17·5 lb. to 7·8 lb. (Hammond, 1921); Southdowns of the same age, from 1921-1932 averaged 71·8 lb.

Moulton (1929) has given a comprehensive survey of the control of quality in meat from the viewpoint of the meat packer. He considers problems of meat storage, meat spoilage, the curing of meats, sausage making, and the treatment of the various by-products which play such an important part in abattoir economy. Hammond (1920 and 1932) published papers on the relative growth and development of various breeds and crosses of cattle and sheep, in which he considered the influence of breed, age, early maturity, and cross-breeding on the killing proportions of the carcase. The scope of his analysis was limited by available data which dealt only with the live weight of the animal, the carcase weight, combined caul and gut fat, pluck, skin and digestive tract. He states that, "there still remains another point of great importance in estimating the most economical breed for the production of meat, i.e., the proportion of bone, fat and meat in the carcase." Hitherto the science of animal nutrition had approached the subject of quality in the animal mainly from the feeding side and had generally stopped short at the digestion of the foodstuffs and the total body weight of the animal. This led Hammond (1932) to make a very thorough survey of the scientific principles involved in the production of meat, in which he considers the physiological, anatomical and practical points of view, working backwards from the end product—meat, and studying the conditions or factors which affect its formation. MacKenzie and Marshall (1917) pointed out that very little was known as to the exact points which differentiate the mutton animal from the wool type. Wood and Newman (1928) analysed beef carcases of various ages and states of fatness in order to determine the percentages of protein, fat and bone in various joints. Such an analysis is interesting from the point of view of food economy, but tells one little of the proportions of muscle, fat and bone as seen by the buyer and which add to or detract from the selling value of the carcase. In 1925 the United States of America started a comprehensive co-operative project in order to determine the factors affecting quality and palatability in meat. The study up to date has yielded much valuable information. Points of excellence in exterior conformation of the carcase have been amply described by various authorities. Hammond and Murray (1934) have investigated the influence of weight, and to a certain extent quality as determined by conformation, on the price of mutton, beef and pork carcases. With bacon pigs Murray (1934) has tackled the problem from the standpoint of fat and muscle measurements.

The primary object of this investigation is to determine the most desirable physical proportions of muscle, fat and bone in mutton, and, as far as possible, in beef, and to trace the factors which influence them. For the sake of completeness further factors affecting the quality of a carcase will be briefly surveyed in the section on beef.

MUTTON.

The eating quality of a carcase refers to the effect of the fat and meat juices, when cooked, on the normal palate. It includes both tenderness and flavour. Quality can be judged to a large extent by visible characteristics such as the condition of the bone (pinkness and softness of the breakjoint signify youth), the colour of the flesh, the texture of the meat and the colour of the " bark ". It is closely linked with and dependent on conformation, finish and carcase weight which are actually the chief determinants of the sales value of a carcase. Because of the strong influence of proportions on carcase quality, and because in mutton the other factors are relatively unimportant, this section will be confined to the influence of proportions as affected by weight, age and breed, with a sub-section on marbling, and a proposed scale of points for judging sheep carcases by measurement.

Material and Methods.

Certain measurements of mutton carcases taken at the Smithfield Fatstock Show for the 12 years 1921 to 1932 inclusive, have been analysed. Where possible statistical methods have been employed. The breed, age and weight of each carcase is recorded. The carcases are cut through at the level of the last rib, so that the proportions of muscle, fat and bone can be seen by the judge and buyer. The following measurements of muscle and fat as seen in this cross-section, and the length of the cannonbone (*meta carpal*) have been taken (see accompanying figure 1). All linear measurements have been recorded in millimetres. Marbling (intra-muscular fat) has been judged by eye; 1 equals most marbling. 5 equals least.

A = Length of Eye-muscle (*Longissimus dorsi*).

B = Depth of Eye-muscle.

C = Thickness of Backfat over the deepest part of the eye-muscle.

D = Thickness of Backfat over the Spinal Process.

X = Thickness of Muscular layer (mixed with fat) over the Ribs.

Y = Thickness of the Fat layer over X.

Cannon = Length of the fore cannonbone taken from the cleft in the knuckle of the distal end to the extremity of the proximal end.

Weight = Weight in pounds of the dressed carcase after the undermentioned parts have been removed. An allowance is made for the weight of the head and the feet on the carcase—6 lb. for carcases weighing under 64 lb., 7 lb. for carcases weighing between 64 and 80 lb., and 8 lb. for carcases weighing over 80 lb.—and this has been deducted from the weight of the carcase by the officials of the show.

M = Marbling.

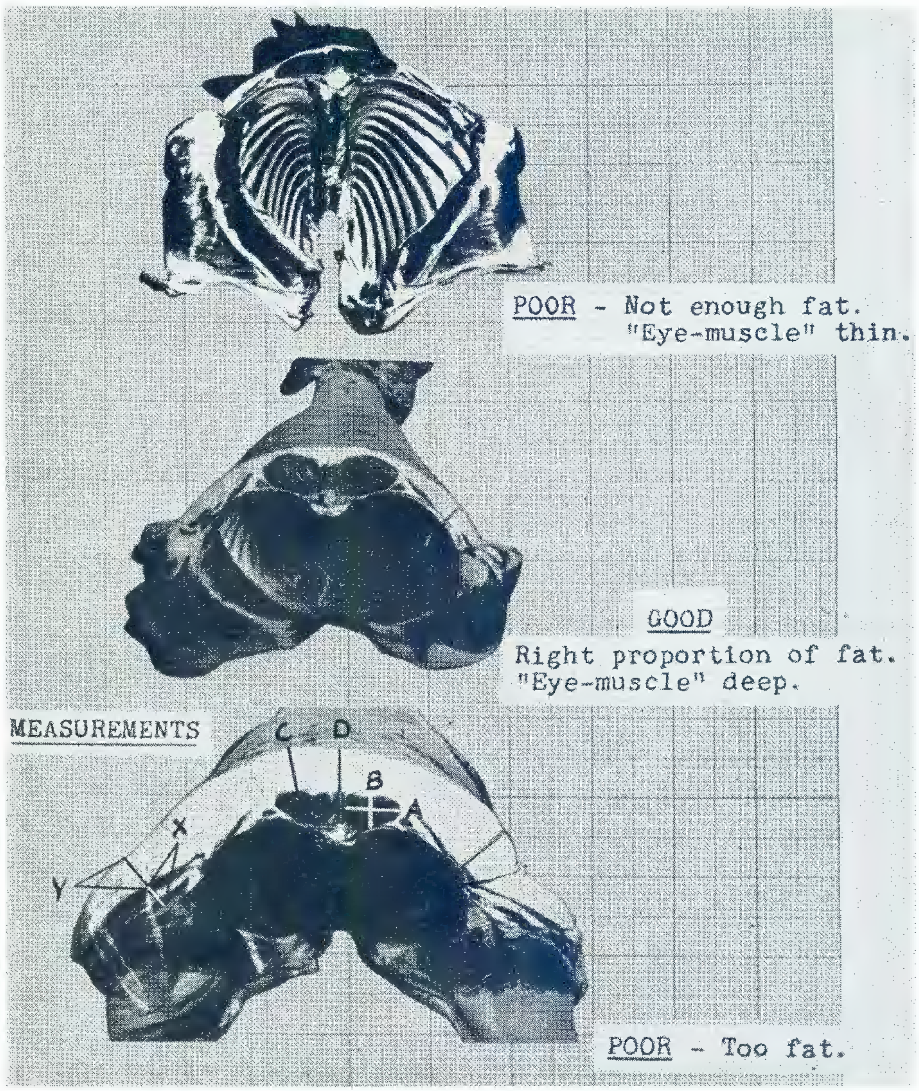
Measurements of X, Y and Cannon are only available from 1925 onwards, M from 1922 onwards.

The carcases are exhibited in age classes (approximately 9 months and 21 months old), and within each age class they are subdivided into Longwoolled and Mountain breeds, Shortwoolled breeds and Crossbreds. Only the breeds and crosses represented by six or more individuals for the A, B, C and D measurements have been averaged out. The average for each measurement in a breed has been found, and in those with a relatively large number of exhibits the Standard Error and Coefficient of Variation $\frac{(\mathrm{SE}+100)}{\mathrm{mean}}$ for each average has been calculated. In those breeds where relatively large numbers were exhibited at both ages, the Percentage Increase in measurement from 9 to 21 months has been worked out and the significance of the differences between the measurements expressed by P, taking as significant the 5 per cent. point, that is the point at which the difference will occur once in twenty times by chance.

In order to see how measurements changed with increasing weight at one age, the animals in those breeds containing sufficient representatives were classed into weight classes (by 10 lb. groups—30-39, 40-49 lb., etc.) and averaged.

Linear Regression Coefficients were worked out at each age to determine the rate of increase in each measurement per unit increase in carcase weight. For 9 months and 21 months, Southdown, Blackfaced Mountain, Welsh Mountain and Cheviot were calculated. Suffolk and Hampshire were calculated for 9 months only, for they had too few individuals in the 21 months' class.

FIG. 1.



Averages, their error and their significance have been worked out for the total of weight classes common to both ages for Southdown, and lumped Blackfaced and Welsh breeds.

Further, in order to ascertain the significance of differences between any two breeds at one age, the significance of differences between all breeds for which the averages has been tested statistically, were calculated.

In order to find how one measurement varied in relation to the other, ratios between various measurements were calculated for weight class averages and for the general averages of each breed.

Winners, 1st, 2nd and 3rd Prize, have been dealt with separately, averages being obtained for all the winners (1933 included) in each breed at the two ages, and the averages for all breeds lumped and divided into weight classes.

In addition to a study of these measurements, facts and opinions have been collected from retail butchers and meat salesmen through conversations and demonstrations in London, Birmingham, Peterborough, Cambridge, etc.

I.—Quality as Affected by the Proportions of Muscle, Fat and Bone in the Carcase.

Introduction.

The proportions of muscle, fat and bone in a mutton carcase are the chief factors determining its value. In outward appearance the carcase should convey the impression of being a solid block of meat with fat distributed evenly over the body. A carcase short in the leg, broad as seen from the top, back and front, long in the body, with a sufficient covering of fat, demands the highest price. The hindquarters should have meat bulging on all sides of the leg down to the hock joint, where a sharp inward curve narrows the leg down to continue on a short light shank. Spencer (1927) has reported that in better quality carcases the circumference of the leg is proportionally greater than the length. The crotch from the hock joints up should form a broad shallow U. Legginess and a small proportion of meat on the leg is often denoted by a long narrow V (see figure, p. 428). The length of the shank is correlated with the length of the cannonbone (Hammond 1932), so that as a measure of this the cannonbone has been measured and in relation to the muscle measurements gives a relative picture of the shanks. A broad, long back with a good spring of rib denotes the possibility of a good loin. The back part of the animal contains the most expensive cuts, and the front quarter containing the less valuable parts should be light in accordance. Since the neck forms one of the cheapest cuts, the shorter and lighter it is, the better.

Butchers in buying carcases look to certain parts for an indication of carcase value. In mutton a good thick forearm is considered to be an indication of heavy fleshing in the rest of the carcase, while the white irregular streaks (" mackerel marking ") radiating over the back vertically to the direction of the spine and down it, are looked upon as signs of " finish " or sufficient fat covering on the carcase.

But outward proportions are but uncertain indications of the value of the carcase as regards proportion of fat to muscle, as evidenced in carcase competitions, where an ideal outward appearance sometimes yields very disappointing results when seen in cross-section. Feeding has become an art in itself and by packing on sufficient fat a carcase is often moulded into the ideal shape, which only on cutting displays the lack of muscular development and the superabundance of fat. No criterion in judging has yet been found whereby the proportions of fat and muscle in a cross-section of the loin can be determined from external appearance. It is only when the carcase is cut through that we can make a study of the proportions of muscle and fat in it.

Carcase competitions at shows allow the public taste to be conveyed into figures. Butcher judges representing the public demand, award prizes to carcases in order of merit. The measurements of such prize-winning carcases, taking the measurements directly, in relation to one another, and in relation to weight, may be interpreted as the public demand. The fat measurements are absolute, that is they stand at an almost fixed figure, irrespective of muscle, bone and weight changes. More than a certain thickness of fat is wasteful and is left on the plate or has to be pared off the joint before it is sold. A slice of meat from a joint with a heavy fat layer is repelling to most people in the London area; too little fat gives it an unfinished, unattractive appearance and influences cooking detrimentally by allowing juices to escape from the lean meat, with a consequent drying and loss of succulence of the joint. Thus is fat an absolute measurement.

Muscle on the other hand is elastic and the more there is within certain weight-controlled limits which will be discussed later, the more do the public like it. Bone which represents direct waste is an all-round loss, and the cry is for a very light-boned carcase. Bone weight may be to a certain extent camouflaged by a shortening and thickening of the bone as has been done in the case of the Southdown breed (Hammond 1932). Although there may be no actual loss in weight of a particular bone, the shortening and thickening brings with it a shortening and thickening of the muscle covering. This produces, as in the case of a leg of mutton, a more attractive joint, allowing of a deeper slice of mutton and a larger area from which such slices can be cut (see figure, p. 428). Waste from the extremity of the joint is reduced, that is there is less shank. In addition to shortening the bone it is also possible to refine it to some extent as has been done with the Aberdeen Angus beef cattle; but too much lightening tends to bring with it a reduction of the thickness of the muscle covering, a factor which has been realized and is being guarded against by suitable breeding. A thickening of the bone in shortening it, with no weight reduction, is preferable to reducing the weight of bone in a carcase by making the bones thinner. Actually then it is rather the long bone, than the somewhat heavy bone that is objected to, particularly in mutton. In beef a bone both light and short is very desirable, but refinement to the extent of destroying the bulge of meat must be guarded against, for the appearance of the uncut carcase goes a long way towards determining its sales value on the wholesale meat markets. The ideal proportions of a mutton carcase weighing about 55 lb. are given on page 398.

How weight, age and breed play a part in determining the quality of a carcase will be shown in the following.

1. Proportions of Muscle, Fat and Bone in Relation to Weight of Carcase.

A light carcase is in greater demand than a heavy one, and the extent to which weight makes a difference to price depends upon the market at the time of selling (Hammond and Murray, 1934). Butchers on the Central Meat Markets of London consider nothing too light and lightness is often obtained at the expense of finish. But the unfinished carcases sell, and at a comparatively high price, for the consumer wants the small three-pound leg. This accounts for the ready sale of 28-30 lb. lamb carcases where some lack of finish is conceded for the sake of lightness. A small advance in weight beyond 30 lb. brings with it a definite demand for correct finish. At the other end of the weight scale the danger of surplus fat combined with the heavier weight of carcase brings down the price in most breeds. When we consider that unnecessary fat is put on in the animal at considerable expense, especially at the younger ages, and that this extra fat in addition to its cost of production brings down the selling price, we find that it is important to determine the weight ranges at which carcases of various breeds attain such proportions as ensure a ready sale.

Table III gives a number of breeds which have been divided up into the weight classes for each age, the measurements for each weight class being averaged out. Owing to the limited number of carcases in many of the weight classes, the averages, especially at the lighter and heavier weights, are not trustworthy and make it difficult to determine the actual curve of the increase. As breeds differ in maturity and size (weight) at the same age, they will be discussed separately for each measurement, but before doing so there are some general trends worthy of note. Diagram I a-g shows for each breed at 9 months old the measurement increase with increase in weight. In general all measurements increase with carcase- weight increase, the slope being continued by the heavier breeds where the lighter breeds leave off, except for the cannonbone where weight seems to have no direct bearing on length, i.e., the breeds differ more widely in inherent length of bone (at the same weight) than they do in proportions of muscle and fat. The extent of differences varies considerably for the measurement taken, but in each breed the tendency on the whole, particularly for the muscle and fat measurements, is a fairly steady and fairly linear increase of measurement with increase in weight.

The A measurement (length of eye-muscle) shows considerable breed fluctuation, there being at the same weight considerable differences in measurement between the breeds. The rate of increase is, however, fairly constant irrespective of breed, and runs through evenly from the lighter classes in the smaller breeds to the heavier classes in the larger breeds.

The B measurement (depth of eye-muscle) shows this to a still greater extent. Initial differences are evident, as for example between Southdown and Blackfaced in the initial weight class of

30-39 lb.; but in increasing there is little difference in actual amount of increase (millimetres) per unit increase in weight, and the graph lines run practically parallel. For example, the Suffolk and Hampshire continue the increase approximately from where the lighter breeds end and at the same rate of increase. Three reasons for weight fluctuations within a breed present themseves, firstly, differences in feeding and management, secondly, differences in individual capacity for gains from birth to time of measurement, and thirdly, small age differences.

With the C measurement (backfat over the eye-muscle) the measurement again increases fairly steadily with weight increase, and except for Southdown which puts on fat very rapidly, again shows a certain parallelism of rate of increase between breeds.

Increases at the D measurement (fat over the spine) are steady, but a great scatter is caused by very marked breed differences which will be discussed subsequently.

The X measurement (muscle on ribs) increases regularly for most breeds, and breed increases run practically parallel except Suffolk and Southdown × Cheviot which show a very rapid rise from the lighter weights.

The Y measurement (fat on ribs over X) increases rapidly and it would seem to be on this part that a great deal of weight is added.

The cannonbone shows a very variable measurement with increase in carcase weight. This indicates that the amount of bone growth is not one of the chief weight determining factors at one age, although bone to a certain extent affords the framework onto which the animal packs its weight. A very heavy Southdown for example had a cannonbone only 115 mm. long, a length equal to that of the cannon average in the lightest weight class.

In Diagram II a and b the rates of increase of the various measurements with increase in carcase weight have been plotted for the Southdown breed, showing the measurement for each weight class as a percentage of the measurement at the weight embracing the largest number of individuals. In order to show the amount of increase of the various tissues in such a way as to compare their rates of increase, a standard of comparison is necessary and the average measurements of the weight class containing most individuals, being nearer the general mean than any other measurements, offer a good basis of comparison. The measurements in order of ascending rate of increase at 9 months are Cannon, A, B, X, Y, D and C. It is clear to what a great extent fat affects the weight of the carcase. At 21 months fat shows the same rapid increase as compared with muscle and bone. In both 9 and 21 months C, D and Y are closely grouped for the lighter carcase weights, diverging at the higher weights to make the fat region over the eye-muscle (C) one of the chief places of fat output in the Southdown.

The point which we wish to emphasize at this stage is the important role that fat plays in increasing the weight of the carcase at any one age (from 9 months on).

(a) Increase of Muscle, Fat and Bone of the Winners compared with Increases of the Breeds at the Same Age.

To determine what ideal proportions are and to find the principles governing the judging of carcases, the winners (Table IV) were grouped into weight classes similar to the breeds (Table III) and compared with the breeds to see where the faults come in which bring down the value of the carcase when weight is added.

9 *Months.* *A.*—In the winners with increase in weight, muscle increases steadily from 55·5 mm. to 64 mm. (only weight classes 40-49 lb. to 70-79 lb. are taken for Winners, since 30-39 lb. and 80-89 lb. are too poorly represented to give reliable averages). The general tendency for the Breeds is also to increase with increase in weight.

B.—Both in Breeds and in Winners B rises steadily with weight increase. Thus the more muscle growth the better.

C.—In the Winners in the 40-49 lb. class C, with a measurement of 6·2 mm., is considerably lower than in the 50-59 lb. class where it jumps to 8·2 mm. From here onwards C keeps almost constant with a rise of only 0·6 mm. in 20 lb. carcase-weight increase. This indicates that fat is an absolute measurement with an optimum development of about 8·5 mm. Comparing this with an average measurement of 7·9 mm. for the Champions (see Table II), the figure 8 mm. seems to be the correct ideal. But with the years a change has come about and the taste for fat as indicated by the Champions has changed (see Table II), so that taking the average of the last five years we have an average of 6·6 mm. as compared e.g. with a general average for Southdown at that weight ($\pm$55 lb.) of 9·8 mm. This then would constitute the optimum depth of fat covering over the eye-muscle, while a depth of 9 mm. may be considered the maximum amount permissible for a readily saleable carcase. The small difference in actual depth of fat made by about 1·5 mm. seems very small indeed, but that much increase in fat depth is readily noticeable by eye; and it must be remembered that 1·5 mm. of fat spread over the fat-covered area of the carcase is sufficient to make a considerable difference, not only to the weight of the carcase, but to the weight of the waste fat on it. In the Breeds, C rises rapidly with weight increase.

In a report issued by the Ministry of Agriculture (1931) it is stated that ½ inch (ca. 13 mm.) of fat over the eye-muscle is sufficient for to-day's requirements, but that in some classes of the trade even less is preferred. Our figures show that in the London trade considerably less finish is preferred, which is very fortunate for the producer who finds it difficult to fatten cheaply.

D.—In the Winners, D rises up to the 60-69 lb. class and then drops slightly. D is a measurement varying very much with breed and the drop at the higher weights of the Winners is due to the fact that in the 70-79 lb. class there are no Southdowns, a breed with a very deep D measurement. That D is not an absolute fat measurement, and that it may vary independently of the absolute fat measurement at C without damaging the carcase, is evident. D in the Breeds increases regularly.

X.—In the Winners, X increases on the whole except for an unexplainable drop in the 50-59 lb. class. X in the Breeds also increases regularly.

Y.—In the Winners, Y to commence with, increases fairly rapidly, but slows to about 0·5 mm. increase for 10 lb. weight increase at the higher weights. In most Breeds Y increases rapidly throughout and the measurements of the Winners indicate that Y from the 55 lb. measurement onwards may be considered as absolute with an optimum depth of about 14 mm. The Champions vary from 10 mm. to 18 mm. with an average of 15 mm. for animals falling in the weight class 50-59 lb. In Champions, however, that is in a single carcase, one unfavourable point may be counterbalanced and outweighed by other good points so that the figure for any single good animal, even a champion, is not as accurate a criterion of the less important measurements of a carcase as the averages obtained from a series of good carcases.

Cannon.—The cannonbone in the Winners increases with increase in carcase weight, jumping up from 55 to 65 lb. as the average is more strongly influenced by the longer legged breeds in the heavier weight classes (see Table IX). Also for the breeds there is a tendency for length increase with weight increase, but it is not so regular since at the higher weights it is not necessarily a big-framed carcase that carries the weight, for often weight is due more to fat than anything else, whereas in the winners weight is very largely due to muscular development.

21 *Months*. *A*.—In the Winners there is a steady increase of measurement with weight increase; not so in the Breeds where considerable fluctuations occur. From one extreme to the other there is an increase, but from class to class many breeds, for example, Southdown and Blackfaced, two of the best represented breeds, show a drop after increasing to a certain weight instead of the regular rise mostly encountered at 9 months. This is because the length of the muscle matures early; consequently at 21 months muscle growth having almost stopped fat goes to make up the weight. The phenomenon of an actual decrease in measurement in some higher weight classes may be caused by the fact that where the muscle growth of the animal is stunted in its initial stages of growth by poor or incorrect feeding (lack of proteins) fat growth supersedes muscle growth and heavy feeding at the end, especially a ration high in carbohydrates, causes the animal to pack on fat very rapidly and rise to a high weight. It would seem that the majority of animals of big weight in some of the breeds are those which have been fed and managed most incorrectly.

B.—In the Southdown, an early maturing breed, the same phenomenon of a falling measurement with increased weight is particularly marked, the measurement increasing from 55 to 75 lb. and thence falling to 95 lb. In the late maturing Welsh and Blackfaced there is a constant rise, for the depth of the eye-muscle is a later maturing dimension than the length, and where the early maturing Southdown has already ceased muscular growth both at A and B, the later maturing Welsh and Blackfaced breeds, although having matured for A, are still growing at B. In the Winners there is a consistent increase; in these, as opposed to the Breeds when the weight increase is chiefly by fat, weight is added more by an increase in muscular development and bone.

C.—As opposed to fat increase in the Breeds which in the case of Southdown for example, is extremely rapid, the fat increase in the Winners having risen to 9·4 mm. in the 60-69 lb. class, takes 20 lb. to increase to 10.6 mm., an increment of 1·2 mm., while for the same weight increase in the Southdown it rises 6·8 mm., and for Blackfaced for 20 lb. (55-75 lb.) it rises 3·3 mm. Fat thus reaches its maximum sales-boundary at 21 months at about 11 mm.

D.—In both Winners and Breeds D increases constantly.

X.—In the Winners X is variable and is probably influenced by breed. In the Breeds it rises constantly with weight increase.

Y.—This measurement increases constantly, rising in the Winners from 55 to 85 lb. by 5·5 mm. This indicates that Y is not so important in determining carcase quality as C which is kept nearly constant with weight increase. In the Breeds, however, the increase in the early maturing breeds is very much greater, the Southdown increasing 12·2 mm. over the same weight range. The later maturing Cheviot increases only 5·8 mm. and the Welsh 6·5 mm. The greatest actual depth of fat is added at Y with weight increase as evidenced by the Breeds, but whether Y actually shows a greater percentage increase than the other fat measurements will be investigated later.

Cannon.—Mostly the cannonbone rises in the Breeds with weight increase. In the Winners there is a peculiar drop from 50-59 lb. to 60-69 lb. accounted for probably by the distribution of the winning breeds over the weight classes (see Table IX). The short-legged Southdown has a stronger influence in the 60-69 lb. class than in the 50-59 lb. class.

(*b*) *The Relation of Measurements to one another with Increase in Carcase-weight.*

In order to ascertain to what extent the proportions of muscle, fat and bone change in relation to one another with increase in weight, a series of ratios have been calculated for the weight classes of the Winners (Table V $a-e$) and a series for the weight classes of the Breeds (Table VI $a-g$).

Ratio $\frac{C}{B} \times 100$ (a): This ratio for the Breeds is no criterion of what the proportion of fat to muscle should be, for a heavy fat covering over a deep eye-muscle might give the same proportion as a thin fat covering over a shallow eye-muscle. Nevertheless since at each weight we have a fair average for that weight, and as the measurements mostly increase, especially at 9 months, a good idea of the relative rate of increase is obtained.

9 *Months.*—In all breeds there is a considerable increase, ranging from 23·2 in the rapidly fattening Southdown to 8·6 in the late maturing Blackfaced. From 50-59 lb. to 70-79 lb. the ratio of the Winners keeps remarkably constant at about 24·0.

21 *Months.*—There is more of an increase in the Winners here than at 9 months, but as compared with the fat increase of the Breeds it is still small, amounting to 1·2 from 60-69 lb. to 80-89 lb., whereas for the same weight increase the Southdown ratio rises 17·6 and the comparatively lean Cheviot 3·7.

Ratio $\frac{C + D + Y}{A + B} \times 100$ (*b*): This ratio combines all pure fat and lean measurements, and where $\frac{C}{B}$ gives an idea of the ratio of the most important of these measurements, $\frac{C + D + Y}{A + B}$ indicates how the total fat to lean changes.

9 *Months.*—In the Winners the increase is by no means regular although in general showing an upward tendency. This is due to breed distribution in the weight classes, the higher proportions at 55 and 65 lb. being caused by the predominating influence of Southdown with its heavy D measurement. However the increase from 45 to 75 lb. of 4·1 is small as compared with 22·9 for Southdown and 12·5 for Blackfaced for the same weight increment, and is a further demonstration of the necessity of keeping down the fat proportion. With $\frac{C}{B}$ the winner ratio remained constant, and the increase here shows that D and Y are not paid so much attention to as C in awarding prizes.

21 *Months.*—Here both the Breeds and Winners show a more rapid increase in the proportion of fat to muscle than at 9 months. Winners increase 9·0 while for the Breeds the extremes of increase for a fat and a lean breed was 31·1 for Southdown and 10·4 for Cheviot.

Ratio $\frac{B}{A} \times 100$ (*c*): This ratio indicates the way and shape in which the eye-muscle develops.

9 *Months.*—In the Winners there is no significant increase, a fixed proportion or roundness of eye-muscle being evidently the desired thing. But in all the Breeds except Hampshire and Kent there is an increase, the amount of increase differing with breed. This means that the animals in the higher weight classes are better grown and that B is an important dimension in determining the value of the carcase since, except for Southdown, the ratio of the winners is throughout higher than that of the breeds.

21 *Months.*—The Winners increase from 55 to 65 lb. and thence remain constant to 85 lb. The Breeds mostly increase up to a point whence a decrease in the higher weights is due to weight added by fat rather than muscle.

With the increase in weight B increases more rapidly than A. Increase in weight is due to thicker muscle, but chiefly to more fat. Heavier sheep may be older, or more likely they have been better fed so that length growth A more rapidly approaches maturity, leaving most increase to depth growth B. Breed difference and rate of maturity are important in determining the ultimate size and shape of muscle and the nature of the weight increase. In the early maturing Southdown the value of deeper muscle with weight increase is nullified by the output of excessive fat; Blackfaced, Welsh and Cheviot, although not too fat, are flat-muscled due partly to slow development. At 9 months the difference between the ratios of the general averages of Southdown and Blackfaced for example is 6·7; comparatively better growth by the Blackfaced (later maturing) up to 21 months reduces the difference at that age to 4·4.

Improvement in muscle development might to some extent be effected by feeding a higher percentage of protein in the ration when the animal is young, and making its most rapid muscular growth. But for commercial purposes it is questionable whether high protein feeding is of sufficient importance under existing conditions to justify the extra expense, for until some criterion is found whereby the depth of eye-muscle can be accurately judged in the uncut carcase, butchers will not be able to discriminate sufficiently between a good and a poor carcase (as regards muscle development) to make a difference in their buying price which will compensate the extra expense in feeding. Those who do produce a first class article, however, will find an expanding market for their product, while those who do not will encounter a poorer demand.

Ratio $\frac{X}{Y} \times 100$ (*d*): This ratio gives the relative development of the meat on the ribs (interspersed with fat) to the fat layer over it.

9 *Months*.—The breeds in general decline in ratio with increase in weight, that is Y has a proportionally greater increase than X. The winners show little increase in the proportion of Y to X and point to the selection of a good thick muscle band on the ribs.

21 *Months*.—Here the Winners and also most of the Breeds show a constant decrease in ratio due to muscle growth subsiding and fat being chiefly responsible for weight increase.

Ratio $\frac{Y}{C} + 100$ (*e*).—This ratio shows how the fat over the ribs increases in relation to the fat over the eye-muscle.

9 *Months*.—For the Winners, from 55 to 75 lb. the ratio remains practically constant, but at 45 lb. there is somewhat less fat at C, and although also less at Y, not sufficiently so to keep constant the proportion. The Breeds show considerable breed variation both between breeds and between weight classes within a breed, e.g. Southdown and Blackfaced (see Table III), and it is difficult at the age of 9 months to determine whether Y or C is the faster developing measurement with increase in weight.

21 *Months*.—The Breeds fluctuate as before, but the Winners, except for a drop at 65 lb. rise consistently, showing that Y increases somewhat faster than C. Two factors make this possible, firstly a greater control of fat thickness in Winners at C with less attention to Y, and secondly an urge with increasing fatness to put on more fat at Y than at C (compare ratios of the general averages at the two ages in the Breeds—Table VI*e*.)

Ratio $\frac{A + B}{Cannon} \times 100$ (*f*).—This ratio indicates development of total muscle in relation to bone. Winners are left out in this ratio and the next, for great breed differences in length of bone influence the averages in the weight classes according to breed distribution. Judges can select more strongly for good muscular development and correct fatness, which to some extent reflect the feeders' science, than for shortness of bone which remains unaltered by the differences in nutrition that cause radical differences in muscle and especially in fat development (Trowbridge, 1918).

9 *Months.*—In general the Breeds have a small but steady rise showing that muscle increases proportionally more than bone.

21 *Months.*—The same tendency to increase exists but to a lesser extent than in 9 months. So for example Southdown from 45 to 65 lb. increases 2·3 at 9 months and at 21 months from 65 to 85 lb. it is 1·6. Blackfaced at 9 months from 35 to 55 lb. increases by 5·7 and at 21 months from 55 to 75 lb. by 4·3. This is explained by the fact that the frame of the animal is formed comparatively early in life. At 9 months muscle is growing more rapidly than at 21 months, influences carcase-weight more and raises the ratio more rapidly.

Ratio $\frac{C + Y}{Cannon} \times 100$ (*g*).—This ratio shows the increases of fat in relation to bone increase.

9 *Months.*—The ratio goes up steadily with weight increase.

21 *Months.*—Here the rise is not as regular and shows a tendency to shoot up suddenly at the end, due in some cases to excessively fat animals, or this plus a drop in cannonbone length.

(*c*) *The Relation between Quality, Weight and Price.*

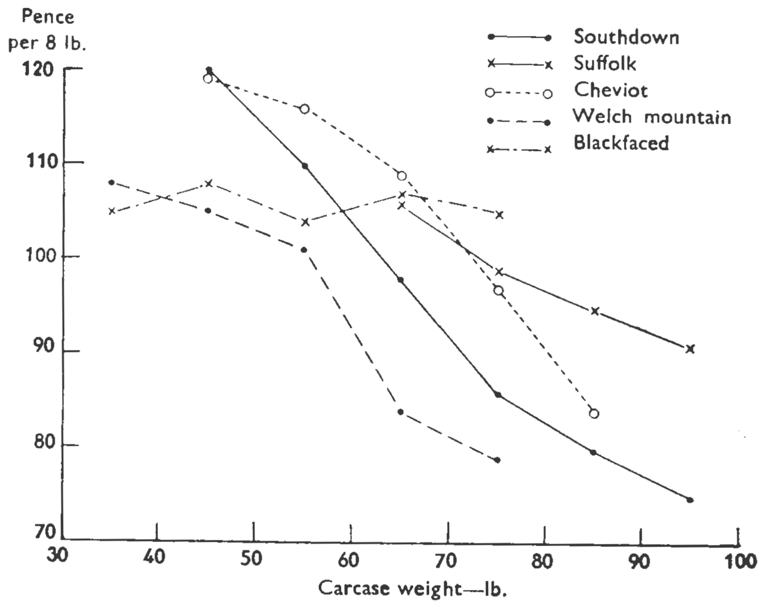
Hammond and Murray (1934) in making a study of the influence of carcase weight on prices, found that with an increase in weight the price per stone (8 lb.) dropped for most breeds analysed (see accompanying Figure 2 from Hammond and Murray).

The increase in weight is closely connected with an increase in the fat proportions of the animal [see Table VI (*b*)] and it is desirable to determine exactly in how far price is influenced on the one hand by weight and on the other by quality. Unfortunately there are difficulties preventing an accurate analysis of the one factor independently of the other, the chief one being the very close connection between weight increase and fat increase. It is possible, however, by a consideration of the various measurements of the better represented breeds at a certain weight in relation to the price obtained at that weight, to determine the effect of quality on carcase price. Table VII affords a comparison of the best represented breeds and the price per stone they made at a carcase weight of 65 lb.

The highest and lowest prices were given for Cheviot and Welsh carcases respectively. The Cheviot is longer and deeper in eye-muscle than the Welsh, has an optimum proportion of fat and has somewhat shorter bone. Comparing the two fattest breeds, Southdown and Welsh, we find the Southdown making a considerably better price than the Welsh, for although slightly shorter in eye-muscle, it has a much better depth, giving the desired roundness of muscle. Although somewhat fatter at C, it contains a little less fat at Y and is better at X; but its greatest advantage over the Welsh is the shortness of bone giving a neat compact carcase. Comparing the Suffolk and Blackfaced which make about the same price, the Suffolk although better in the eye-muscle is a shade under-finished, poor at X and longer in the leg. Proportions of muscle, fat and bone work together in varying degrees of importance in determining the value of a carcase. With increasing weight C and Y are particularly important as will be shown later.

FIG. 2.

Prices for Carcases of Different Weights in Various Breeds of Sheep.



Hammond and Murray in drawing up their Weight-Price Tables ignored the age classification owing to but small differences in price between 9 and 21 months' carcases of the same weight. If fat affects the quality of the carcase, then this disregard of the age factor is further justified by a study of Table VI (*b*) which shows how fat increases in relation to muscle with weight increase. So for example there is in Southdown an increase of 35·7 in ratio at 9 months and 39·6 at 21 months for a weight increase of 40 lb. in each case, while at one weight (65 lb.) there is an age difference of only 8·4. (65 lb. was chosen because it contained a large number of representatives at each age.) Hammond and Murray found much greater differences in price due to weight than to breed. Their findings are supported by our figures of fat increases with weight increase, for breed differences are small as compared with weight differences. At the age of 9 months the maximum difference in ratio due to breed between

Southdown, Blackfaced, Welsh and Cheviot was 16·2 at 55 lb. and 21·8 at 65 lb., while difference in proportion of fat to lean due to weight increase was in the Southdown for example 49·7. At 21 months the breed differences are equally small compared with the weight differences. This leads to the conclusion that the influence of breed on the proportion of fat to lean is less important than the influence of weight.

That the proportion of fat increase in the carcase is closely correlated with price is seen from Table VIII, where the increase in ratio of fat to lean in the carcase with weight increase is compared with the decrease in price ascribed to a weight increase (due largely to fat). Except in the case of the Blackfaced there is a drop of about one penny for a one per cent. increase in ratio of fat to lean for the breeds, from the lightest weight to the highest weight sold.

The different prices obtained by breeds at the same weight and with weight increase are readily explained on the basis of quality, All breeds, except Blackfaced, drop in price per stone with increase in weight (Hammond and Murray, 1934), and the reason for the comparatively high and level price maintained by Blackfaced is that although increasing its proportion of fat to lean with weight increase, the increase is such that the amount of fat remains within the taste-limits of the public (except for the end weight which is somewhat high at C). At the commencement the Blackfaced makes a lower price per stone than the light, well finished Southdown, owing to its lack of fat, but as the weight increases the animal gets nearer the optimum proportions, and what is lost in price due to weight increase (larger joints) is gained by the carcase obtaining the correct amount of finish at a heavier weight. The Welsh at 9 months [Table VI (*b*)] has very much the same proportions of fat to lean as Blackfaced at 9 months, but in the 21 months' Welsh there is at the higher weights a rapid increase in the proportion of fat and it is reflected in the price-weight curve where the drop in price at the heavier weights is rapid due to this excessive addition of fat. On the same argument the comparatively high prices obtained for the heavier Cheviot or Suffolk carcases can be ascribed to the fact that they maintain a comparatively low proportion of fat. Quality then, especially the amount of fat, seems to play a very important part in determining the carcase price.

(*d*) *Carcase Weight.*

A study of the distribution of the prize-winning carcases in weight classes for breeds and in general (see Table IV) reveals a difference in the best prize-winning carcase weight between 9 and 21 months' animals. Most winners at 9 months fall in the 50-59 lb. class while at 21 months most are in the 60-69 and 70-79 lb. classes. It is certain that the higher weights are not more desirable than the lighter weights, but as the majority of carcases shown at 21 months are fairly heavy the scope of judges for selection of good carcases from the lighter weights is limited.

Knowing now the weights at 9 months of the winners, and knowing that the majority of winners fall within the 50-59 lb. class, it is possible from a consideration of the measurements at this weight to fix with some certainty (for the present-day taste) the proportions of the carcase, especially as regards fat, which the judges consider to be suited to demand. The proportions at 21 months are not taken into consideration, for as previously pointed out and as evidenced by twelve out of thirteen champions being 9 months old (see Table II), the 21 months' animal is not in general suited to the light-weight fat-finicky trade of to-day, and seems to be in the Smithfield Show classes more as a heritage from the days when big fat sheep did literally and metaphorically carry weight.

In the 9 months 50-59 lb. class in which most winners fall, the following are the measurements at the average weight at 55·3 lb.:—

A = 58·1 m.m.	D = 13·7 m.m.
B = 33·9 m.m.	X = 10·5 m.m.
C = 8·2 m.m.	Y = 13·5 m.m.
Cannon = 125·9 m.m.	

In this series only the fat measurements C, and to a lesser extent Y, should be considered absolute. In view however of the changing taste for fat in favour of the leaner carcase, C is better fixed at 7 m.m. which is just slightly below the average for the years 1928 to 1933; 9 m.m. will mark the upper limit at which a carcase is still readily sold. The fat measurement at D is subject to breed variation and is not important in influencing quality. The muscle measurements A and B have no upper boundaries and may be as large as can be obtained within the weight class fixed by the fat measurement C. The measurement at X which consists of muscle and fat may develop within the weight class determined by C as much as it can, for it forms an edible part of the chop. The cannonbone measurement marks the theoretical upper limit and any decrease in length is welcomed, but since great breed differences exist the limit cannot be accepted as binding.

The weights at which breeds are best slaughtered, that is, the weights at which they attain the optimum proportion of fat in the carcase, will differ considerably according to breed; but economy as well as quality must play a part in determining the slaughter weight best suited to the pocket of the producer. The highest prices per stone are paid for the lightest carcases, up to a point, irrespective of finish; so Cheviot at a light weight but underfinished condition makes a better price than when correctly finished at a higher weight. Again the light but badly finished Blackfaced at 35 lb. makes the same price as the correctly finished Suffolk at 65 lb. (see Fig. 2, p. 396); in the Blackfaced, lightness makes up for price lost for poor finish, in the Suffolk correct finish balances the tendency for price to fall with weight. In two breeds with the same optimum finish at different weights, e.g. Southdown and Suffolk, the lighter breed will generally make the best price. With finish the same at the same weights, breeds make approximately the same price, e.g. Cheviot, Blackfaced and Suffolk.

The weight at which a farmer sells his sheep will be largely dictated by the cost of production. In raising the weight of a sheep he has more to sell but at a lower price per stone. If production costs are low, the extra weight may bring in more money per head sold. Where production costs are high, the reverse may be true and the producer may find it more remunerative to sell out at a lighter weight. The weight at which the animal is best sold must be determined by the producer himself, and only when a stage in marketing is reached where carcases, produced under intensive farming conditions, are paid for according to grade, will guide weights, which tell the farmer at what weight each breed has reached its optimum proportions, be of value.

The following table presents the approximate weight in lb. at which carcases of some of the more widely exhibited breeds and crosses will, under existing feeding methods, attain the optimum back-fat measurement (C=7 m.m.):

Breed.	9 *Months.*	21 *Months.*
Southdown	40	50
Kerry Hill	50	?
Welsh	50	45
Blackfaced	55	50
Cheviot	55	55
Kent	55	—
Hampshire	55	—
Suffolk	65	—
Southdown × Cheviot	45	(50)
Suffolk × Cheviot	55	(60)

( ) = Weights doubtful.
— = Too fat and heavy to produce marketable carcases at this age.
? = No representatives.

The weight at which breeds are fit to be marketed depends largely on the feeding and management to which they are subjected. The 9 months' exhibit is "kept going" from birth, i.e. there is no store period; the 21 months' animal undergoes a store period and is subject to manipulation to suit it as nearly as possible to market requirements. All breeds are suitable for slaughtering at 9 months, but at 21 months the large, early maturing breeds are not, becoming too fat and heavy. Improvement could doubtless be effected by feeding the animal less after muscle has developed.

Hammond and Murray (1934) in finding the price-weight correlation lumped the 9 and 21 months' classes because they found little difference in the price of carcases of the same weight. Consequently carcases might as well compete in weight groups as in age groups. If breeds competed in weight classes, by trial and error they would soon find the weight level at which their proportions are suited to the trade. At the light weights Southdown, for example, would beat the unfinished Suffolk of the same weight, but at the heavier weights the

Suffolk would come into its own and beat the Southdown with its heavy fat accumulation. Judging carcases, judges, in addition to a consideration of quality, are confronted with the problem of weight in making their decisions; but if carcases competed in weight classes they would be unhampered by weight considerations and would be free to pay attention entirely to quality, as defined by conformation and proportions of muscle, fat and bone: a drawback of the weight class system might be that breeders, finding a sphere in which their heavier stock could easily compete, might lose the incentive to breed animals suited to the light-weight trade. It is to be hoped, however, that the commercial value of a light carcase as compared with a heavy one will be sufficient stimulus to maintain their efforts to obtain light weight combined with early maturity. Some heavy breeds are, however, still necessary, for there are certain parts and classes of trade in the country which require fairly heavy mutton.

For several years now the weight class system, instituted by Hammond of the School of Agriculture, Cambridge, has worked perfectly for pork and bacon and there is no reason why the system should not prove equally valuable for mutton.

Conclusions.

1. Of the tissues, fat is the most important factor in determining the quality of a carcase. The back fat (C) and the rib fat (Y) are the most important, with C the more important of the two. Thickness of fat over the spine (D) does not affect carcase quality. Of the muscle measurements, the depth of eye-muscle (B) is more important than the length (A). A well muscled rib (X) is favoured. Long bone is detrimental to quality.

2. At one age there is little breed difference in the amount of muscle increase with increase in carcase weight. Fat increase is chiefly responsible for weight increase at one age, and most fat is added on the ribs (Y), especially at 21 months. Next to fat, muscle has the greatest influence on weight, and bone the least.

3. With increasing weight at any one age the winning carcases add weight chiefly by muscle increase, and not by fat increase as do the individuals of the breeds which are not winners.

4. The optimum back fat thickness (C) is about 7 mm., and the maximum ensuring a ready sale of the carcase is about 9 mm.

5. There is a close connection between weight, fatness and price of carcase.

6. Most breeds make top prices at their lightest weight, irrespective of finish. Weight is more important in determining price in a light carcase than quality, while at higher weights quality is more important.

7. All breeds are capable of becoming too fat at 9 months old, the point at which the breed becomes overfat depending, apart from feed, on how rapidly it matures.

8. The influence of weight on the ratio of fat to lean in the carcase is greater than the influence of either breed or age.

9. At shows weight classes should be substituted for age classes.

2. Proportions of Muscle, Fat and Bone in Relation to Age of Carcase.

The differences between mutton and lamb and the age factors which make for tenderness and other qualities associated with young meat will be considered later when quality in beef is discussed.

In mutton, age is of little importance in affecting the eating qualities of the meat between the ages of 9 and 21 months. The chief influence is in the way quality is affected by change of proportions of muscle, fat and bone in the carcase, and by weight changes. In this section the extent to which age affects the quality of the carcase will be determined.

(*a*) *Age Changes in General.*

Age changes in general usually involve an increase in all measurements and an increase in weight. The extent to which measurements increase will be largely dependent on the rate at which breeds mature and the way in which they are handled.

Diagram III depicts the percentage increase of the various tissues of the Welsh from 9 to 21 months. Throughout, fat has a much larger percentage increase than muscle, and the fat over the ribs* (Y) has a greater increase than fat over the eye-muscle (C). Eye-muscle depth (B) makes more increase than eye-muscle length (A), and bone increases less than muscle. The above is borne out when the tissues of the Southdown at the two ages are expressed in relation to one another (see Diagram IV). These relative increases of the different tissues from 9 to 21 months are the same for all breeds, but the actual amount of increase of each separate tissue depends much upon the breed and will be discussed under that heading.

(*b*) *Age Changes Considered Independently of Weight Changes.*

In order to find to what extent (under existing systems of management) age, as independent of weight, affects the proportions of the carcase, those breeds with a large number of representatives were taken and averages of the measurements found for a number of carcases falling in weight classes common to both ages, so that at each age the weight averages were constant. Where more than one weight class was involved, where breeds of similar type were lumped in order to obtain large numbers, care was taken that each weight class at 9 and 21 months should contain exactly the same number of

* For explanation of measurements see p. 384.

individuals of each breed, averaging as nearly as possible the same weight. Blackfaced and Welsh, both small, late-maturing breeds, were lumped together. The distribution was arranged as follows:—

The Grouping of Weights for Age Comparison at Constant Carcase Weight.

Breed.	Weight Class.	9 Months.		21 Months.	
		No. of Individuals.	Average Weight.	No. of Individuals.	Average Weight.
			lbs.		lbs.
Welsh	40–49	7	46·9	7	46·9
,,	50–59	9	53·7	9	55·1
Black-faced	40–49	4	46·8	4	46·8
,,	50–59	15	55·2	15	55·0
,,	60–69	8	63·4	8	62·1
Total	—	43	54·3	43	54·3
Southdown [for A., B., C., D.]	50–59	10	—	12	—
	60–69	36	—	31	—
	70–79	4	—	4	—
Southdown [X., Y., Can]	50–59	10	—	9	—
	60–69	22	—	23	—
	70–79	1	—	4	—

Since with Southdowns alone, breed influence is excluded, no attempt was made to equalize the numbers from which averages were obtained at 9 and 21 months. To get the average weights equal in 9 and 21 months it was impossible in cases where all sheep could not be taken from a weight class, to practice random selection for weight; but the measurements for those weights selected are entirely random, for no attention was paid to measurements in choosing carcase weights.

Table X gives the averages of the measurements. In determining their value the coefficient of variation was used and the 5 per cent. point (an arbitrary one) taken as the point up to which the results could be considered reliable. This limit is seldom exceeded and then very slightly. Differences between 9 and 21 months were tested for significance. Southdown gave significant differences for C and D, while Blackfaced + Welsh was significantly different for A, Y and Cannon only. The lower fat measurement in Southdowns for the older animal reflects methods of management and feeding which set out to keep down the natural inclination of the Southdown to add fat. Although differences in muscle measurements in favour of the older animal are statistically insignificant, they must necessarily account for equality in weight. In Blackfaced + Welsh the considerable drop in eye-muscle length (A) from 9 to 21 months can only be explained on the basis of a system of management which partially neglects, in its earlier stages of growth, the animal designed for carcase classes at the older age, the necessary feeding to attain condition being practiced only shortly before show time. The earlier maturing length of eye-muscle seems to be affected more than depth, which, reaching maturity later, is probably capable of availing itself of the higher plane of nutrition provided shortly before the show. Theorizing, it would seem that while there is growth, improvement may be affected, but once the age is reached where growth would stop under most favourable conditions, permanent stunting results. Better feeding of the young Southdown and earlier maturity tends to obviate the effect experienced by the later maturing and more poorly fed animal. Differences in rate of maturity are apparent from the Cannon-bone averages; the Southdown matures its bone before the age of 9 months, Blackfaced and Welsh later. Within limits, bone growth is not stunted by lack of nutrition and will grow at the expense of other tissues (Trowbridge, 1918).

(c) *The Effect of Age on the Nature of Weight Increase.*

In order to see how muscle, fat and bone increased with increase of weight in the carcases at 9 months and 21 months, linear Regression Coefficients showing the increase in millimetres of each measurement with each pound increase in carcase weight, were calculated for the two ages of those breeds which were sufficiently well represented. It is realised that from the biological standpoint an absolutely linear regression is unlikely, but since most of the measurements for the breeds increase very nearly in a linear manner (see Diagram I a-g), the principle of a simple regression has been used, not to afford a table on which to read off a measurement at a certain weight, but rather to give an illustration of the rate of increase of the various tissues at different ages.

The results are given in Table XI. Certain growth tendencies are obvious throughout, but only in a few cases are the differences of these tendencies between the two ages of statistical significance. Insignificance is probably due to the considerable amount of variation in the individuals, and in some cases to a rather limited number of individuals. But the directions indicated by those few measurements showing regression coefficient with differences between the two ages of statistical significance, is borne out in most cases by the other coefficients in spite of the differences being insignificant.

Taking first the eye-muscle length (A), the Welsh at 9 months shows a rapid increase with weight increase; at 21 months there is a decided slackening off of the increase with weight increase from 0·344 mm. at 9 months to 0·155 mm. at 21 months (see Diagram V *a*). The Southdown for the depth of eye-muscle (B) shows the same thing, decreasing in rate of increase between 9 and 21 months from 0·156 mm. to 0·0698 mm. (see Diagram V *b*). Coming to the back-fat and rib-fat measurements (C) and (Y), we find that in Welsh the fat increase of C of 0·107 mm. at 9 months rises to 0·208 mm. at 21 months (see Diagram V *c*). In the same way in the Southdown Y rises from 0·260 mm. to 0·405 mm. (see Diagram V *d*). This leads to the conclusion that the effect of ageing is to decrease the rate at which muscle is added with increase in weight, while the rate of fat increase rises as the muscle increase drops. In the four breeds in which age comparisons are possible, namely Southdown, Blackfaced, Welsh and Cheviot, the principle is borne out by the regression coefficients of three out of the four breeds for every measurement. So for A, Southdown, Welsh and Cheviot follow the direction indicated for muscle increase diminishing in rapidity of increase with age; for B, Southdown, Welsh and Blackfaced; for C and D, in the opposite direction, Southdown, Welsh and Blackfaced; for Y, Southdown, Welsh and Cheviot.

Regression coefficients for X show no significant age differences. The Cannon-bone increases significantly with weight at both ages only in the Southdown, but the small age difference is insignificant. The Blackfaced and Welsh at both ages, and the Cheviot at 9 months show no correlation between length of bone and carcase weight, which means that weight is dependent only upon the development of muscle and fat, whereas in the earlier maturing breeds, Southdown, Suffolk and Hampshire, the size of frame helps to determine weight.

Conclusions.

1. With weight increase due to age, fat increases most, muscle next and bone least. Depth of eye-muscle increases more than length of eye-muscle. Fat on the ribs increases more than fat over the eye-muscle.

2. In early maturing breeds muscle can have reached its maximum amount of growth at 9 months. In later maturing breeds muscle grows beyond this age.

3. Increase in the weight of an animal is a much more potent factor in affecting proportions of muscle, fat and bone in the carcase than is increase in age independent of weight changes. What these latter are will depend on the rate of maturity of the breed and the system of management adopted.

4. Muscle grows faster in a young animal than in an old animal. Fat grows faster in an old animal than in a young animal.

(3) Proportions of Muscle, Fat and Bone in Relation to Breed.

Breed plays an important part in determining the sales-value of a carcase at any one age. Sheep may be conveniently divided into two groups, early maturing breeds and late maturing breeds; the majority of the breeds with which we deal fall into the former group. This classification is only approximate and no sharp line of difference can be drawn.

For our purposes maturity may be considered as that stage of growth where the fatty tissue over the " eye " of loin has reached the optimum depth of 7 m.m. Some breeds reach this stage at an early age, others comparatively late (Hammond, 1921). Feeding has much to do with the speed and manner in which a breed grows (Trowbridge, 1918). The inherent early maturing capacity of a sheep may be severely retarded by providing insufficient food or food of the wrong kind for the full expression of the growth urge (Callow, 1935), while no amount of feeding, however good, could bring on earlier maturity in those breeds which naturally develop more slowly (Hammond 1921). When a young early maturing animal is full-fed on a ration containing a high percentage of carbohydrates and oils, a suitable depth of fat for slaughtering may be rapidly attained, but at the expense of loss in carcase quality due to the lack of protein necessary to allow a full development of muscle. By withholding fattening foods the laying down of fat may be retarded. This practice is adopted by feeders when early maturing breeds have to be shown in carcase classes at comparatively old ages, such as is the case at the Smithfield Show where carcases are shown at approximately 9 and 21 months old.

The rates at which breeds mature go hand in hand with the food supply, natural or otherwise, of the area on which they are found; in the arable districts where natural grazing has been supplemented by root crops and improved grasslands, we find breeds such as the Southdown and Suffolk. These two breeds, although both develop rapidly, represent two somewhat divergent types. The former grows in muscle for a short period and soon begins to put on considerable quantities of fat, so that a carcase is ready for the butcher at an early age and light weight. The latter also grows rapidly, but continues its growth of muscle for a longer period before adding fat in any quantity and, because weight is added more rapidly by muscle growth than by fat growth, at the same age the Suffolk is a heavier sheep than the Southdown, but with a thinner fat covering. This puts them in two categories: (1), a sheep which attains sufficient fat for marketing at an early age and light weight and (2), a breed which attains a high weight at an early age without a proportionally great fat covering. The effect on price has been discussed on pages 395-397.

Contrary to these are the late developing breeds (both in muscle and fat) for example the Scotch Blackfaced. Grazing is sparse and conditions hard, and the animal grows slowly and remains comparatively small. Nature limits the size of the animal in a particular area largely to the food she can provide for its maintenance, that is, the size of the animal is dependent on its environment (Hammond 1935). So elephants exist in jungles and places where a vast amount of food is available; with vegetation less dense the maximum size of animal which can be supported decreases so that on the worst of lands only rabbits can exist. A less exaggerated scale of comparison is offered by the small merino sheep on the comparatively poor grazing of the South African Karoo and the large Lincoln on the better grazing of the county of that name in England.

(*a*) *Comparison of Purebred and Crossbred Averages with a Standard.*

In the 9 months age class averages have been found for 11 pure breeds and 9 crosses (Table XIIa). To obtain an idea of the value of the averages the standard errors and coefficients of variation were calculated for 10 of the pure breeds and 3 of the best represented crosses. At 21 months (Table XIIb) the averages of 7 pure breeds and 6 crosses were found; of these, 3 crosses were not treated statistically. (It was impossible in the circumstances to treat each breed and cross statistically.) In some of the poorly represented breeds the averages are subject to a comparatively large error, but nevertheless offer some crude indication of the development of each part measured.

The age classification of carcases into groups of 9 months old and 21 months old is only approximate. The figures quoted below giving the correct ages of some of the breeds shown in the carcase classes from 1896-1913 were published by Hammond (1921).

"Lambs."			Wethers.		
Breed.	No. of Sheep.	Average Mths./ Days.	Breed.	No. of Sheep.	Average Mths./ Days.
Blackfaced	16	7–2	Blackface	33	19–2
Cheviot	67	7–3	Welsh	20	19–2
Kent	11	8–2	Cheviot	76	19–3
Suffolk	154	9–0	Suffolk	61	20–1
Southdown	80	9–0	Southdown	57	20–3
Hampshire	84	10–0	Hampshire	35	21–3

Although not of great importance in this analysis, especially at 21 months old, these age differences should be borne in mind in the following breed comparisons.

In order to compare breeds a standard of comparison was fixed in each case where comparisons were drawn, by taking the average of all the winners (1st, 2nd and 3rd prize) in the 9 months and 21 months classes. In the following diagrams (which are all plotted to the same scale) the breed averages are expressed as a percentage of the winner averags. The muscle measurements offer excellent standards of comparison when weight of carcase is taken into consideration; the fat standards are slightly high since the taste for fat has decreased somewhat in the last years (see Table I).

Comparison of breed averages with a standard made up of the average prizewinners, although not affording an accurate picture of breed values (carcase weight is not taken into consideration) is a means of showing up their differences.

9 *Months A*—(Length of eye-muscle) Diagram VIa.—Only light breeds or crosses lie significantly below the standard, and they lack but little. No breeds fall far short in length of eye-muscle.

B—(Depth of eye-muscle) Diagram VIb.—Only the heavy breeds have an average higher than the standard and then only slightly; the majority lie well below the standard and illustrate the strong selection practiced by judges for a deep eye of loin.

C—(Fat over eye-muscle) Diagram VIc.—Only the late maturing breeds which are also fairly young (see above) are rather lean. Most of the breeds and crosses are too fat for the present day demand. It should be noted, however, that most come from flocks where feeding conditions are good, and that under South African conditions of poorer nutrition it might be advisable to use breeds which were too fat under good nutritive conditions.

D—(Fat over dorsal spine) Diagram VId.—In depth of fat over the spine very great breed differences exist, but economically they are unimportant. A short spine means short bone.

X—(Muscle on ribs interspersed with fat) Diagram VIe).—That the amount of muscle on the ribs is of some importance to the butcher is clear from the fact that the majority of breeds lie below the standard. Depth of X and depth of B at constant fatness, are probably associated.

Y—(Fat on ribs) Diagram VIf.—Most breeds are too fat.

Cannon—Diagram VIg.—The majority of breeds are somewhat leggy. The length of bone that a breed may carry to advantage will of course depend largely on the weight of the animal, i.e. size of joint.

Weight.—Diagram VIh.—Although a number of breeds lie below the standard, none of them can be considered too light. The Suffolk, Dorset Down, Hampshire and Southdown × Dorset Down are definitely too heavy to suit the trade and since these breeds are all too fat, it would be to their advantage to reduce weight by carrying only the right amount of fat. Even breeds such as the Ryeland, which lie close to the weight standard but carry far too much fat, would gain more in price by an increase in carcase quality than would be lost by a drop in weight. No carcase is too light for the London trade.

21 *Months.*—*A*—(Length of eye-muscle) Diagram VIIa.—At this age the length of eye-muscle in most breeds has almost fully developed and there is no length deficiency of any importance in any of the breeds.

B—(Depth of eye-muscle) Diagram VIIb.—Most of the breeds are somewhat shallow. The two heaviest breeds, Suffolk and Hampshire, markedly exceed the standard on account of their great weight.

C—(Fat over eye-muscle) Diagram VIIc.—Most breeds are much too fat. The natural tendency of the older sheep is to lay on fat and producers should guard very carefully against over-fattening in this class.

D—(Fat over the dorsal spine) Diagram VIId.—Distinct breed differences are apparent but have no influence on carcase quality.

X—(Muscles on ribs interspersed with fat) Diagram VIIe.—Statistically, breed differences are insignificant. The development of Suffolk × Southdown is however outstanding and is the only one to lie above the standard. Other breeds and crosses could all be improved.

Y—(Fat on ribs) Diagram VIIf.—The majority of exhibits are too fat.

Cannon—Diagram VIIg.—As in the 9 months class there is selection for shorter bone, but on the whole there is less fault to find at 21 months than at 9 months. Bone matures early (Hammond, 1932) and grows little from 9 to 21 months, while the rest of the carcase becomes considerably bigger, so that the proportion of bone becomes less than at 9 months.

Weight—Diagram VIIh.—There is a trade (restaurants and hotels) to consume a limited number of the heavy carcases, but Hampshire and Suffolk are too heavy even for this.

(*b*) *Comparison of Some Purebred and Crossbred Averages at Constant Weight with a Standard* (*the average of all winners at that weight*).

Above, the general averages of breeds have been compared irrespective of what weight they average, and measurements will be largely dependent upon the weight of the breed. For a stricter comparison of breed proportions, such breeds as are sufficiently represented have been compared at a constant weight with standard averages obtained from the averages of winners falling within the same weight class. At 9 months the standard is set by 54 winners averaging 55 lb., at 21 months by 45 winners averaging 65 lb. (see Table IV). As limited numbers of individuals in some of the breeds and crosses prohibited division into weight classes, only 7 pure-breds and 2 crossbreds could be compared at 9 months, and only 4 pure-breds at 21 months. A comparison of breeds at the same weight gives a good indication of their comparative carcase quality at a useful butcher's weight. For averages of the breeds and numbers of individuals see Table XIII. (Diagrams VIII and IX are drawn to the same scale as VI and VII.)

9 *Months*. *A*—(Length of eye-muscle) Diagram VIIIa.—Very little fault can be found here with the breeds. The Southdown is perhaps rather poorly developed compared with the standard, because it is a short-boned breed and length of muscle goes with length of bone (Hammond, 1932). Breed differences are insignificant.

B—(Depth of eye-muscle) Diagram VIIIb.—Most breeds fall below standard. Southdown has a comparatively good depth of muscle while the Hampshire is just over the standard.

C—(Fat over eye-muscle) Diagram VIIIc.—According to standard the majority of breeds are too lean, but judging from the low fat standard of the last few years the difference is of little importance. Those breeds lying over the standard are too fat.

D—(Fat over dorsal spine) Diagram VIIId.—The high standard set at D may be accounted for by shortness of bone in the prize-winners (28 per cent. Southdowns), for shortness of bone means a good shaped leg of mutton (see Fig., p. 428). Since the breeds are mostly not as short in the bone as the average of the winners, they have a shallower D measurement than the winners and fall below standard.

X—(Rib muscles interspersed with fat) Diagram VIIIe.—Kent is the only breed seriously lacking development; Cheviot might be improved; other breeds below standard do not lack much and several are actually better than the standard.

Y—(Fat on ribs) Diagram VIIIf.—Most breeds fall below standard, but in the light of the present day taste it is doubtful whether this is of any importance. Certainly, nowhere are breeds excessively fat at this weight, nor are any great breed differences apparent between three diverse types of sheep, Southdown, Blackfaced and Suffolk × Cheviot.

Cannon—Diagram VIIIg.—Bone is longer for most breeds than the length set by the standard, especially the excessively long-boned Kent. Bone develops early and in the lighter, less well covered carcase shows off to greater disadvantage than at the higher weights.

In comparing these breeds at the same weight as the prize-winners it will be seen that the defects as a whole are not nearly so marked as when the same breeds are compared at the same age, independent of weight, i.e, if exhibitors sent their sheep more nearly to these weights they would on the whole come nearer to the ideal proportions.

21 *Months A*—Length of eye-muscle) Diagram IXa.—This small drop below standard of Southdown and Welsh is negligible.

B—(Depth of eye-muscle) Diagram IXb.—As before, muscle depth is lacking, except for Southdown which is sufficiently developed.

C—(Fat over eye-muscle) Diagram IXc.—None of these breeds are excessively fat or lean at 65 lb.

D—(Fat over dorsal spine) Diagram IXd.—There are big breed differences of no commercial importance.

X—(Rib muscles interspersed with fat) Diagram IXe.—Some improvement is necessary for Welsh, Cheviot and Blackfaced, not a great deal it is true, but the deficiency is consistent enough to show that like B, X is one of the measurements to which judges attach importance. Both entail thickness of muscle.

Y—(Fat on ribs) Diagram IXf.—Blackfaced and Cheviot are perhaps somewhat lacking in finish, while Welsh is considerably too fat. Blackfaced and Welsh, both late maturing breeds and very similar in conformation and other measurements, are sharply different as regards the amount of fat carried on the ribs at this age.

Cannon—Diagram IXg.—Only the Blackfaced and Welsh, the late maturing breeds, are too long on the leg.

(*c*) *The Increase and Percentage Increase of Measurements from* 9 *to* 21 *Months.*

In finding the increase in measurement of the various parts, it is hoped that it will be possible by comparing the amounts of increase, to gain some idea of the comparative growth tendencies of some of the breeds. The measurements at the two ages have been compared statistically for those breeds having sufficient representation, in both the 9 and 21 months class.

Breeds and crosses dealt with are Southdown, Suffolk, Hampshire, Kent, Cheviot, Blackfaced, Welsh, Suffolk × Cheviot, Southdown × Cheviot and Southdown × Kent. For Suffolk, Hampshire and Suffolk × Cheviot no comparisons could be drawn between measurements X, Y and Cannon at the two ages because of too few carcases on which these measurements were taken. Table XIV gives the increase in millimetres of each measurement from 9 to 21 months, the percentage increase and the significance of the increase. The results are illustrated by Diagram X.

A—(Length of eye-muscle) Diagram Xa.—Three purebreds and one crossbred show an insignificant increase, which may be due partly to maturity of muscle length before the age of 9 months, and partly to small numbers of individuals at one or other age affecting the calculation. It is significant that both length of eye-muscle and length of cannon-bone show no significant increase in the Cheviot and Kent, whereas in cases where the length of bone increases significantly,the length of muscle follows suit (see Table XIV).

B—(Depth of eye-muscle) Diagram Xb.—All breeds increase significantly, and with a larger percentage increase in general than A, B is again seen to be the later maturing dimension.

C—(Fat over eye-muscle) Diagram Xc.—The majority increase significantly, for the natural tendency of the animal is to fatten with age. The 9 months level and the amount of increase of Blackfaced, Welsh and Cheviot, all lean (late maturing) breeds is almost the same, with a high percentage increase in proportion to the actual increase. The Southdown is so early maturing in fat formation that it puts on a large proportion of its fat before 9 months, and to prevent over-fatness producers are very careful to add little from that time on.

D—(Fat over spine) Diagram Xd.—There is considerable breed difference, the later maturing breeds having the largest percentage increase.

X—(Rib muscles interspersed with fat) Diagram Xe.—The fact that the leaner breeds, which add a considerable percentage of fat, also have the greatest increase at X, is further evidence of the influence of fat in thickening this measurement.

Y—(Fat on ribs) Diagram Xf.—The fat increase (millimetres) over the ribs is not very different for most of the breeds, except Welsh, which increases very rapidly at this part. Blackfaced with a much smaller actual increase has a comparatively large percentage increase, i.e. without the danger of becoming over-fat it can add more fat at these old ages (9-21 months) than the early maturing breeds.

Cannon—Diagram Xg.—The Kent and Cheviot either mature their bone by 9 months, or smaller carcases have been selected at the older age. The point is an interesting one—it is possible that some breeds mature early in bone and muscle but late in fat? The

Cheviot is claimed to be early maturing (British Breeds of Livestock, 1927) but only 26 per cent. of the exhibits are in the 9 months class. Is this due to difficulty in getting them fat at an early age, and if so, is it due to the natural restlessness of the breed, or to some inherent capacity militating against fat output?

Weight—Diagram Xh.—There is a similarity in weight increase between all breeds except Suffolk and Hampshire, which add considerably more weight than the rest.

It is difficult to determine from the muscle measurements which of the breeds is most early maturing. A small percentage increase at B for example may mean either that muscular growth has slackened off and that the animal has all but reached muscular maturity, or it may mean a normal (if slow) increase, indicating late maturity. A large percentage increase, however, as in the case of the Suffolk, would mean that a great deal of growth has occurred after 9 months and would signify late maturity. It appears most likely that between these comparatively advanced ages the percentage increase would signify the rate of maturity, i.e. the larger the percentage increase the later the muscular maturity. In general, in the muscle and bone measurements there is a tendency for the actual increase (millimetres) to be closely associated with the amount in percentage increase. This does not hold in the fat measurements, the reason being probably the difference in the rates at which breeds mature in fatness and the control exercised by producers to prevent overfatness.

It is known that the sequence of growth is first the development of bone, then muscle, and lastly fat, but it is unknown whether (under similar conditions) the ratio of the rate of bone growth to rate of muscle growth, or rate of muscle growth to rate of fat growth is the same for all breeds. If it is the same, then breeds should follow in sequence of amount of muscle increase in the same order as they stand for bone increase, which is not the case in our figures. In none of the breeds shown is bone influenced by feeding practice, for even on a comparatively low plane of nutrition it makes normal growth (Trowbridge, 1918), but muscle may well be influenced by malnutrition. This, and very few individuals in some breeds from which averages were obtained, prevent any conclusions being drawn from this data and the above remarks must be considered strictly in the light of speculation.

(*d*) *The Value of the Breeds and their Crosses as Judged by Carcase Quality.*

It is now proposed to discuss the carcase value of those pure breeds and crosses for which measurements have been averaged out at 9 and 21 months. Only where a marked deviation from the standard set by the winners occurs will any importance be attached to the figures. Breeds are shown in the following classes:—

(*a*) Longwoolled and Mountain breeds.

(*b*) Shortwoolled breeds.

(*c*) Crossbreds.

At 9 months all three, muscle, fat and bone measurements are important. At 21 months, while this still holds, muscle is relatively less under-developed than at 9 months and we are particularly concerned with the degree of success producers have achieved in showing carcases of the various breeds with the right amount of fat. Although excess fat over and above the standard appears to be no greater than at 9 months (Diagram VIc. and VIIe.), it must be borne in mind that the excess measurement is based upon a standard, which because most 21 months exhibits are too fat, is a good deal higher than the public requirements. Selection against long bone remains equally strong at both ages.

The weight factor greatly influences the quality of the carcase, and from a cursory examination of the facts it would seem unfair to compare all breeds, irrespective of their weights, with a standard set by carcases averaging a certain weight. Since, however, this average weight (9 months—55 lb., 21 months—65 lb.) is arrived at by a majority of the prize-winning carcases being of that weight, it indicates a standard (particularly at 9 months) which judges do not consider too heavy. From the exhibitor's point of view it might have been preferable to compare the average measurements for each breed with the averages of winners similar in weight to the breed average, but owing to an uneven distribution of the 1st, 2nd and 3rd prize-winners in the weight classes giving an unfair bias to some weight classes, and to there being very few representatives in the lighter and heavier weight classes, this method was abandoned. Another way would be to compare each breed with the averages of the winners for that breed, but again poor representation of prize-winners in some breeds and uneven distribution of 1st, 2nd and 3rd prizes makes the method unreliable. Furthermore, not all the breeds and crosses dealt with are represented among the winners. Consequently it was deemed best to compare with one sound standard, the general average of the prize-winners.

In addition Table XV $\frac{A \times B}{(\text{Cannon})}$ was calculated to provide figures whereby the shape of muscle in relation to bone length could be compared between breeds. If the ratio is considered as amount of muscle to bone length then values for breeds with heavy bone, e.g. Southdown, that is bone with large volume as compared with length, will be slightly over-estimated, values for breeds with light bone, e.g. Welsh, will be slightly under-estimated as regards the meat to bone ratio. (Ratios such as the above need to be investigated and tables drawn up whereby the relation of one part of the carcase to another at a certain age can be obtained from the physical analysis of some easily obtained cut such as the last rib. This would greatly simplify physical analyses of carcases, besides allowing the meat handled to make a reasonable price since the carcase would suffer a minimum of mutilation.)

In the following the number of individuals from which averages were obtained are given for each breed. The first number is for A, B, C and D measurements and weight, the second for X, Y and Cannon. Breeds are grouped into the classes in which they compete at the show.

Shortwoolled Breeds.

Southdown. 9 months (146 and 111 individuals).—A sheep of medium weight, rather short in the eye-muscle but with excellent depth in comparison to length, indicating good thick muscle formation; bone is very short and the $\frac{\text{muscle}}{\text{bone}}$ ratio good (see Table XV); it is shown somewhat too fat. Altogether an outstanding mutton breed if not fattened beyond the right proportions. In its class Southdown has by far the largest number of prize-winners.

21 months (94 and 66 individuals).—Muscle and bone proportions are good but it is shown too fat. It formed a high percentage of the winners.

The Southdown is a good sheep at both 9 and 21 months and the chief criticism is that it is over-fat at both ages. By far the most widely exhibited breed up to 1933, it has 163 individuals shown at 9 months as compared with 88 for Blackfaced, the second highest breed. In 9 months 16 per cent. of the total number of Southdown exhibits were 1st, 2nd and 3rd prize-winners (see Table IX), while 11 out of the 26 winners obtained 1st prizes. At 21 months Southdown has 102 individuals as compared with 77 for Blackfaced and Cheviot, the next highest breeds. Again, of the total of 25 prize-winners, 11 obtained 1st awards.

Suffolk. 9 months (73 and 39 individuals).—The heaviest breed exhibited; a well-meated carcase but muscle rather poorly developed on ribs; too fat, and very long on the leg (shanky).

21 months (10 and 5 individuals).—Much too heavy and much too fat, but the eye of loin is well developed although muscling on ribs is rather poor. At this age the Suffolk, because of its weight, is almost useless to the London butcher.

The extent to which the breed is too heavy is shown by the fact that the average weight of the Suffolk winners at 9 months is 69 lb. compared with a breed average of 82 lb. The Suffolk is a good meaty, comparatively lean breed, and apart from its great weight the chief criticism is shankiness. That can be remedied by breeding.

Hampshire. 9 months (42 and 22 individuals).—A heavy carcase with a well developed, long, deep, round eye, in proportion more like the Southdown than any other breed; rather poorly muscled on ribs, too fat and too long on leg. Has won few prizes.

21 months (8 individuals).—Excellent eye of meat rather poorly muscled on ribs, much too fat, bone too long and carcase too heavy; right out of prize-winning class at this age.

A considerable amount of weight reduction would be the result of showing the carcase with the right amount of fat.

Dorset Down. 9 months (10 individuals).—Too heavy, and comparable with the Hampshire in weight. Length of muscle is good, but depth only just reaches standard; muscle on ribs is good, but the carcase is too fat.

Kerry Hill. 9 months (14 and 9 individuals).—A moderately heavy breed with an eye-muscle sufficiently long but lacking in depth, poorly muscled on the ribs, too fat over the "eye" and too long on the leg.

Ryeland. 9 months (7 and 6 individuals).—Of medium weight, the eye of loin and muscle on ribs fall below standard; it is shown very much too fat and is a little long on the leg for the weight. The $\frac{\text{muscle}}{\text{bone}}$ ratio is poor (see Table XV).

The Ryeland is most heavily criticised for its excessive fatness, carrying as it does approximately twice the optimum amount of fat. We have no doubt that methods of feeding and management are to blame. Even if the muscle cannot be improved, fatness can certainly be controlled.

Cheviot. 9 months (26 and 14 individuals).—A medium weight carcase with good long but shallow eye of meat and shallow rib muscles; according to standard slightly deficient in fat but in view of the changing taste in favour of lean meat it is unimportant. It is slightly longer on the leg than is ideal for the weight. Leanness, in spite of quality deficiencies in muscle and bone, enables the Cheviot to make comparatively better prices than the well muscled, but on the average overfat Southdown. At 9 months Cheviot has won no prizes (because it has to compete with the Downs and not the Mountain breeds).

21 months (73 and 38 individuals).—Still a fairly light carcase with eye-muscle lacking depth, and rather poor on the ribs; fat depth and shortness of bone come up to standard. At this age the Cheviot has many prizes to its credit—13 out of the 77 exhibits received prizes.

At 9 months the Cheviot has no outstanding virtue except its leanness, at 21 months where most breeds are overfat its success is due to the same thing. Of the breeds at our disposal it is probably the slowest in maturing its fat. Muscle and bone on the other hand mature rapidly. As a mutton breed it fattens too slowly to be remunerative; as a carcase at 21 months it is distinctly valuable.

Longwoolled and Mountain Breeds.

Kent or Romney Marsh. 9 months (18 and 12 individuals).—Rather heavy; eye-muscle sufficiently long but lacking in depth; poorly muscled on ribs; somewhat fat and very long in the bone with a poor $\frac{\text{muscle}}{\text{bone}}$ ratio. The Kent has produced 4·3 per cent. of the total number of winners, but, competing as it does with the Mountain Breeds, the competition is not so keen as in the case of the short-woolled breeds. Like the Hampshire, the breed has obtained no first places.

21 months (12 and 6 individuals).—The muscle is still poorly developed, the carcase is too heavy, much too fat, and overlong on the leg.

The Kent, as exemplified by Smithfield exhibits, is a poorly muscled breed. Too much importance should not be attached to this criticism for the breed is poorly represented and a definite criticism would be unjust.

Leicester. 9 months (7 individuals).—The exhibits vary greatly. In general, length of muscle is satisfactory, but depth is very deficient indeed. The carcase is much too fat and the leg extremely shanky. Two carcases, however, managed to obtain prizes, one getting a first award, its chief virtues being lightness (43 lb.) and leanness (5 mm. at C), a fairly good depth of " eye " for its weight, and fair rib muscles. (It was notable that judges in 1933 gave prizes to very lean carcases compared with former years.)

Blackfaced Mountain. 9 months (82 and 53 individuals).—A light carcase with a rather poorly developed eye of meat lacking particularly in depth. (The breed is shown at a comparatively young age of 7 months.) Rib muscles are moderately developed. The cannon is moderately short, but the $\frac{\text{muscle}}{\text{bone}}$ ratio is poor. Compared with the standard the carcase is rather lean. The breed has many prizes to its credit.

21 months (72 and 39 individuals).—Still a comparatively light carcase with a better proportioned " eye " than at 9 months, although still below standard; muscle on ribs could be better; the fat development is just right; length of cannon conforms to standard but considering the weight of the carcase is perhaps a little long. The $\frac{\text{muscle}}{\text{bone}}$ ratio is poor. Of the 30 prizewinners, out of 77 exhibits 11 gained 1st Prizes.

The Blackfaced, because of its lightness, late maturity and consequent leanness, is one of the best breeds for producing meat at the older ages. At 9 months the breed is a little lean, for the fat over the eye-muscle (C) is raised from 6·5 mm. in the general average to 6·8 mm. in the average of the winners, while the weight average goes up from 48 to 51 lb. It is suggested that animals intended for the 9 months' class be done a shade better.

Welsh Mountain. 9 months (63 and 55 individuals).—What has been said of Blackfaced at 9 months old holds almost exactly for the Welsh Mountain, except that the Welsh is rather better finished on the ribs than the Blackfaced. In consequence the Welsh holds 15 per cent. of the total number of winners as opposed to 11 per cent. by the Blackfaced. Out of 66 exhibits, 17 gained prizes. Like the Blackfaced, the average Welsh measurement at C of 6·4 mm. has been pushed up to 6·8 mm. in the winners and the weight from 43 lb. to 48 lb. In view of the lightness of the carcase and sufficient finish on the ribs, however, it is not advisable to show the Welsh any fatter.

21 months (46 and 41 individuals).—A light carcase but very shallow in the "eye " and poor in rib muscles; the right amount of fat over the " eye ", but somewhat too fat on ribs. It would seem

that infiltration of fat between the muscle layers in the X measurement occurs less in the Welsh than in most other breeds, and that fat is laid down chiefly at Y. The cannonbone is rather long. The $\frac{\text{muscle}}{\text{bone}}$ ratio (Table XV) is the poorest of all the breeds, but it should be remembered here that the bones of the Welsh are thin and so this is exaggerated. The result of this ratio, however, based as it is on volume of muscle to length of bone, is that the shape of the leg of mutton is poor (see p. 412 where this is explained). These faults give the Blackfaced the advantage at the older age as evidenced by the fact that the Welsh produced only 7·7 per cent. of the total number of winners at this age as compared with 25·6 per cent. by the Blackfaced. The breed shows the tendency to lay on a great deal of fat over the ribs as the animal grows older and (or) heavier. The Welsh nevertheless at present provides one of the best carcases both at 9 months and 21 months, for it has the important attribute of leanness over the eye-muscle.

Crossbreds.

Suffolk × Cheviot. 9 months (61 and 36 individuals).—A medium heavy carcase with a good long sufficiently deep "eye", up to standard on rib muscle thickness and rib fat, but slightly too fat over the " eye ", and rather long in leg. The $\frac{\text{muscle}}{\text{bone}}$ ratio is good. Five of the twelve winners obtained 1st awards.

21 months (14 and 7 individuals).—A somewhat heavy carcase with good muscle development except on the ribs, not too long on the leg, but too fat. The $\frac{\text{muscle}}{\text{bone}}$ ratio is excellent.

At 9 months the cross is a good one except that it is a little heavy and too fat. At 21 months it is definitely too fat and heavy. By reducing fat, and hence weight, the quality would be greatly improved.

Southdown × Cheviot. 9 months (34 and 24 individuals).—A carcase of medium weight, insufficient depth of " eye ", rather weak rib muscles, but with a good short leg; too much fat over the eye, but the right amount on the ribs. Four out of the eight winners obtained 1st prizes.

21 months (18 and 11 individuals).—A medium weight carcase with sufficient muscle development except on ribs, a short leg, but too fat. Nine out of the twenty exhibits won prizes.

With a deeper eye-muscle at 9 months and slightly leaner, and considerably less fat at 21 months, the cross would be a very good one. Short bone accounts for a good percentage of prizes.

Southdown × Kent.—9 months (16 and 10 individuals)—A medium heavy carcase lacking eye-muscle depth, moderately well muscled on ribs, too fat and somewhat long on the leg.

21 months (14 and 13 individuals)—The criticism is similar to that at 9 months. The cross is one with no outstanding fault.

Southdown × Dorset Down.—9 month (7 individuals)—A rather heavy carcase with a good " eye " of muscle, good muscle on ribs, somewhat long on the leg, and very much too fat. The $\frac{\text{muscle}}{\text{bone}}$ ratio is high. The average is however obtained from exhibits which vary considerably. By not carrying excessive fat, the carcase would be reduced in weight and of good quality.

Southdown × Welsh.—9 months (7 individuals)—A medium light carcase deficient in eye-muscle and rib muscle development, short of leg, but too fat, especially over the " eye ". The cross because of lightness and shortness of bone should be a good one.

Southdown × Suffolk.—9 months (8 individuals)—A medium heavy carcase with good muscle development, a nice short leg, but slightly too fat. If this cross were shown a little leaner it would be an outstanding example of good proportions. The $\frac{\text{muscle}}{\text{bone}}$ ratio is excellent. As it is, only two of the eight carcases exhibited have obtained prizes (2nd and 3rd prizes respectively).

Suffolk × Southdown.—9 months (15 and 8 individuals)—A medium weight carcase, a little shallow in the " eye ", well muscled on ribs and carrying the right amount of fat, the cannonbone is a little long. Of the 15 carcases exhibited, a 1st and 2nd prize have been obtained.

21 months (10 and 8 individuals)—A rather heavy carcase with excellent muscle development all round, especially on the ribs; the shank is not too long and the $\frac{\text{muscle}}{\text{bone}}$ ratio is excellent. Fat depth over the " eye " is right, although above standard on the ribs.

At 21 months the carcase is attractive, chiefly because it carries the right proportion of fat and is packed with meat. As a result, of the 11 carcases exhibited, 6 were prizewinners, 3 of them 1st prizes, and one of these a champion.

Ryeland × Cheviot.—9 months (12 and 10 individuals)—A fairly light carcase with the " eye " of meat sufficiently long but very much lacking in depth; muscle on ribs is underdeveloped; the leg length is fairly good; fat proportions are about right. The $\frac{\text{muscle}}{\text{bone}}$ ratio is poorest of all the crosses.

21 months (10 individuals)—A medium weight carcase with a good length of eye, but a little shallow; well muscled on the ribs but rather long in the leg and a little too fat over the " eye ". Half of the exhibits at this age won prizes, two being 1st. These individuals had very good muscle development, were not too fat for their weight and merited their awards.

Southdown × Suffolk-Cheviot.—9 months (10 and 9 individuals)—Of medium weight, the carcase has sufficient length of " eye " but lacks depth. On the ribs it is sufficiently thick at X, but is too fat as also over the " eye ". The leg is not too long.

21 months (6 individuals)—A comparatively light carcase, lacking in muscle thickness; far too much fat over the eye-muscle but the right amount on the ribs; the cannon is not too long. (These criticisms are based on too few individuals to be of much value.)

The cross has the advantage of lightness, and if shown leaner at both ages it should be in the running for prizes, for the $\frac{\text{muscle}}{\text{bone}}$ ratio at both ages is comparatively good.

General Discussion.

The main fault to find with most of the breeds and crosses is that they are too well " done ". It is necessary that a carcase should carry sufficient finish to allow it to cook properly and to look attractive, but over-enthusiastic feeding as practised by most producers has defeated its object, and instead of raising the quality of the carcase has overshot the mark and dragged it down by packing on (at considerable cost) excessive fat. Either the producer is unaware of the demand for lean meat or he does not fully appreciate the fattening capabilities of some of the breeds he uses. The latter is probably the case. Comparatively little is known of nutritional requirements for optimum growth in sheep, and it is impossible to lay down rules for any fixed feeding practice because of the difference in breed requirements, individual differences within a breed and differences in the quality of the grazing; but certain it is, that if high quality is to be attained at an early age, a high protein content is essential to grow out the muscle to advantage.

We agree with the opinion so often expressed that prize-winning is to a great extent a matter of luck in hitting off just the right proportion of fat, but as the percentage of winners in the different breeds show, the first essential is right conformation and weight. Careful selection for blocky conformation in the young animal, where muscle and not fat conveys the chief impression of build, that with sufficient exercise and correct feed to keep the animal growing steadily in muscle from birth onwards, will go a long way to guide " luck " in the right direction.

Feeders of heavy sheep such as the Suffolk are distinctly handicapped with the weight factor, and this brings us to an important problem with which the practical breeder and producer is faced, whether to aim at quality or quantity. For example, in aiming at the ideal, the Suffolk sheep should be bred shorter on the leg. This would undoubtedly lead to a somewhat shorter body and reduced weight, but from the quality point of view more would be gained by lessening the weight of the carcase and shortening (not thinning) the bone, than would be lost by a somewhat shorter trunk. Practically speaking and under existing conditions of marketing, it is doubtful whether such a course would be remunerative. Undoubtedly quantity is paying rather better at the moment than quality. Calculating from data by Hammond and Murray (1934), Southdown carcases of 45 lb. (the weight at which quality is highest in the Southdown) demanded 56 shillings at 9 months, while Suffolk carcases of 95 lb. at the same age, although much too fat and heavy, made a price of 90 shillings. Unfortunately no data regarding the cost of keep is available. Further data stressing the greater influence of weight above quality on returns was got from the Cambridge University Farm, where the following results were obtained with 150 lambs of equal age consisting of 75 Suffolk × Border Leicester-Cheviot and 75 Southdown × Border Leicester-Cheviot:

Cross.	Live Wt., on Farm.	Dead Wt.	Price per Lamb.	Killing Percentage.	Average Price per Pound.		Grading.		
					Live.	Dead.	Select.	Prime.	Good.
	lb.	lb.	£ s. d.		Pence.	Pence.			
Suffolk............	5,977	2,803	1 17 3	46·9	5·6	11·9	13	51	11
Southdown.........	4,971	2,337	1 12 6	47·0	5·8	12·3	56	19	—

No doubt the Suffolk cross lambs eat more than do the Southdown cross, but because the Suffolk cross grows more rapidly in muscle it will make more economical gains than the Southdown and it is felt that in spite of any extra food consumption will turn out to be more remunerative than the animal which adds weight more slowly.

It is clear that weight influences the returns to the farmer more than does quality, and until prices react more strongly to quality, it will continue to pay many farmers better to give attention more to bulk than to quality. It is a short-sighted policy but justifiable (in Great Britain) in the absence of marketing regulations whereby the quality of a carcase is an important determinant of the price paid for it. The public, however, demand a certain amount of quality, and, as in the case of lamb, when British producers did not supply the demand, New Zealand stepped in with her high grade Canterbury lamb and practically captured the market. In the years 1927-1931, 57 per cent. of the total mutton and lamb consumed in Great Britain was imported. (H.M. Stat. Office, 1931.) The chief means of improving the present condition would seem to be to cheapen, simplify and regulate an intricate and wasteful marketing mechanism, and centralise slaughter houses in the larger consuming areas into a few well run concerns capable of using every scrap of carcase residue, which instead of going to waste as at the present, could be manufactured into valuable by-products.

To return to the problem of heavy breeds of sheep in relation to quality, it has been proved that they can be satisfactory at a light weight—a Suffolk carcase weighing 59 lb. at 9 months old won the championship in 1933. The difficulty with a light carcase from a heavy breed is to get the bone sufficiently short. That can be remedied only by breeding. Calculating from the figures of Hammond and Murray (1934), the Blackfaced (105·2d. per stone) and Cheviot (105·9d. per stone) made the highest prices per stone in the Smithfield show sales ring, and the Suffolk (97·4d. per stone) the lowest, the two former not because of outstanding conformation, but because of the lightness and leanness of the carcase.

Improvement for carcase quality may be summarized by the advice: Breed light, short-legged animals, keep the result growing steadily by means of sufficient food of the right kind, and beware of over-fattening. The old adage that, "Half the breeding of an animal goes in at the mouth" is only too true.

(*e*) *Observations on Crossbreeding.*

The object in this section is to determine to what extent crossbreeding affects the proportions and weight of the offspring. Table XVI supplies the general averages of measurements of some breeds, averages obtained as a result of the cross and the averages (bracketed) which would be expected if the offspring lay intermediate between the parents. In the circumstances, as there is no standardised method of feeding and management, it is impossible to attach a great deal of importance to fat measurements in a cross. The muscular development offers opportunity of more accurate interpretation in that in most cases producers attempt to force an optimum development. Bone is perhaps the least affected by methods of production. Ritzman (1923) states that bones, because of their comparative stability against fluctuating variations caused by feed, climate and health, offer a fairly reliable basis of measurement.

In crossbreeding fatstock for the butcher, the popular object is to combine the virtues of both parents in such a way as to produce better progeny than either pure breed under the given conditions could produce. So for example, a Down breed possessing early maturity may be crossed with a Mountain breed possessing later maturity and a strong constitution. The resultant progeny have sufficient constitution on rough grazing with a small allowance of concentrates to make good use of the early maturing factor introduced by the Down breed.

Diagram XI a-h portrays the fluctuation of the crosses (at 9 months) around the expected intermediate, the actual crossbred measurement being expressed as a percentage of the expected intermediate measurement. All diagrams are drawn to the same scale.

A—(Length of eye-muscle) Diagram XIa.—The majority of crosses lie slightly under the expected mean. Only the Southdown × Dorset Down has an outstandingly high average, higher actually than the higher parent, the Dorset Down, but the number of individuals concerned (7) is small. Fluctuations from the expected intermediate are small.

B—(Depth of eye-muscle) Diagram XIb.—Greater fluctuation is apparent here, and still the mean is mostly somewhat below the expected mean.

X—(Muscle on ribs interspersed with fat) Diagram XIc.—There is little more variation from the mean than in B. It is strange that the Southdown × Dorset Down which for A and B comes out high, should lie so low at X. An average from only 7 individuals may account for the inconsistency.

Cannon—Diagram XId.—Fluctuations from the mean are but small except in the case of the Southdown × Dorset Down, and this is in accordance with the long eye-muscle of the cross.

C—(Thickness of fat over eye-muscle) Diagram XIe.—Coming to the fat measurements far greater fluctuations are apparent. Most crossbreds are fatter than would be expected.

D—(Thickness of fat over spine) Diagram XIf.—Nearly all crossbreds lie far below the expected mean. We are unable to explain this result.

Y—(Thickness of rib fat) Diagram XIg.—There seems to be no tendency either way, considerable fluctuation from the mean existing but not nearly as much as at D.

Weight—Diagram XIh.—Mostly the crossbreds are lighter than would be expected. There is considerable variation in the amount they differ from the mean. A high weight for the Southdown × Dorset Down is in accordance with its great development of muscle and fat.

Definite conclusions from these results are not justified for they are not absolutely comparable. Fluctuations may be due either to differences in feeding, management, or type of animal selected, to genetic or physiological reasons, or to age differences. Hammond (1921) compared the weights of purebred and crossbred sheep and their carcases (1896-1913). In the live classes the weight of the cross was nearly always greater than the intermediate between the parents. In the carcase classes only two crosses offer sufficient individuals for comparison. The following compares his figures and ours at 9 months:—

	Crossbred Weight. lb.		*Intermediate Weight.* lb.
Southdown × Suffolk	86·5	—Hammond—	82·4
	69·4		68·5
Suffolk × Cheviot	69·2	—Hammond—	78·9
	62·7		67·8

In spite of considerable weight differences between them caused by the demand for lighter carcases, his figures and our's vary from the expected mean in the same direction for each breed. The Southdown × Suffolk is slightly above the expected result, while the Suffolk × Cheviot is lighter than would be expected. In the first case two breeds (Southdown-Suffolk) which are both regarded as early maturing and are normally kept under good nutrition are crossed and the lambs being reared under these conditions grow slightly better than the expected mean, whereas the second cross (Suffolk-Cheviot) is between an early maturing breed and a late maturing breed, the former being kept under good and the latter under poorer nutrition. Since the ewe is of the latter type the lambs will be reared under poorer conditions, and so the cross is below the expected mean.

The popular belief of "hybrid vigour" due to crossing is not supported by our figures, nor by those of Ritzman (1923) who crossed Southdown and Rambouillet. In fact his figures and ours show rather a tendency for the weight of the F_1 to lie below the expected intermediate. The Southdown and Rambouillet are approximately the same weight but different in body proportions, while our crosses are often between breeds widely divergent in weight. Crossbreeding results are nevertheless similar; also in the more detailed analysis, in the few cases where our measurements overlap, they are mostly in agreement. So, where we find the length of the eye-muscle measurement (A) somewhat below the intermediate, Ritzman's "width of loin" is similarly deficient. The length of cannonbone (in his case foreleg) in both cases closely approach the intermediate. He finds the length of spine in F_1 below the mean. If thinness of fat over the spine is any criterion to length of spine, our results are in most cases diametrically opposed to his.

Ritzman and Davenport (1920) find a clear suggestion that all bones of the body, or in fact bones of a group, such as a limb, do not inherit size in similar proportions from one or the other parent where two unlike races are crossed. In other words, some form of dominance seems to exist in certain measurements. They state that while a cross gives an offspring which in the sum of its measurements approximates to the intermediate, there is considerable evidence that in some instances this intermediate condition is retained through a differentiated size inheritance of individual bones or units, i.e. a differentiated inheritance of associated parts. Pearson (1903) in humans, Hatai (1907-8) in albino rats, and MacDowell (1914) in rabbits, have shown that in size crosses different characteristics do not inherit equally. Punnett and Bailey (1918) have shown that in the rabbit, size and early maturity are transmitted independently. Various experiments in crossbreeding (Goodale, 1932) show that in spite of there being apparently a high degree of homozygosity of quantitative characters, results are often obtained which lie either above or below the intermediate result to be expected if the genetic constitution of the parents were homozygous. This led Goodale (1932) to postulate the theory that the frequent lack of absolute intermediacy in crossing two apparently pure lines can be explained by dominant genes which exist in varying degrees of heterozygosity.

That "hybrid vigour" is often evidenced in the F_1 cannot be denied. East and Hayes (1919) have demonstrated the effect of "hybrid vigour" in crossing two intensively inbred strains of maize. Castle and Wright (1916) and Detlefsen (1914), crossing wild and domestic varieties of guinea pig, and Boyd (1914) and Goodnight (1914) in crossing the bison with domestic cattle, have obtained offspring larger than either parent. Where the types of animals crossed are very widely separated or very intensively inbred, "hybrid vigour" seems to be common in the offspring. Livesay (1930) inclines to the theory that an outcross will always contain genes making for vigour which are not present in an inbred race, while Castle (1920) suggests that increase in vigour may be due to increase in metabolic stimulus which results from the chemical differences in unrelated gametes.

Whatever the reason may be, in crossing different breeds of farm livestock, where the genetic constitutions are more or less akin, the hybrids seem more commonly to be quantitative intermediates. Ritzman (1931) states that even in the more contrasting cross of

Zebu with other races of cattle, the hybrid does not excel in any individual traits of the better parent; in size, based on weight, the intermediate predominates. Schutte (1934) in crossing various beef breeds with native cows found no marked effect of heterosis. Castle (1909) in crossing different sizes of rabbits reports intermediacy in the offspring. Based on his own experiments, and on a critical review of the literature he (1920) has summarised the behaviour of crossbreeding as follows:—" When animals or plants are crossed which have racial differences in size or other characters, in respect of which each race shows continuous variation about a different mean, the F_1 progeny are of intermediate size ".

It is interesting from the producers standpoint to note that Hammond (1921), Ritzman (1927) and Castle (1916) are in general agreement that the F_1 are not more variable than the parent pure breeds, even when the breeds differ considerably in size.

The extent of uterine nutrition has a great effect upon the size of the progeny at birth. Both Humphrey and Kleinheinz (1908) and Mumford (1901) have found that it is the size of the ewe and not the size of the ram which determines the size of the lamb. This means a different start in life, for not alone has the bigger progeny a larger frame and body to start with, but it has an abundant supply of milk, while the offspring from the smaller dam, growing faster than the normal after birth may find that as it gets heavier so the nutrition becomes insufficient to allow of the fullest expression of the growth urge. In the reciprocal cross of Southdown and Suffolk a difference in results is explained by this. In the length of eye-muscle (A) the Southdown dam gives progeny with slightly smaller development than offspring from the Suffolk dam. In the later maturing depth measurement (B) the difference is much more marked. The principle does not hold for bone, but in both cases bone differs very little from the expected mean and it is known (Trowbridge, 1918) that bone development is little affected by nutrition and will grow normally, at the expense of the other tissues, provided that animal is not very greatly underfed. The lambs of the Southdown ram and Suffolk ewe are a little fatter than those of the reciprocal cross, but this is hardly sufficient to account for the big weight difference of 13·1 lb. in favour of the former.

Results indicate a somewhat smaller growth of muscle and a greater growth of fat in the crossbred than would be expected, which may mean that early maturity is obtained at the expense of muscular development. Hammond (1920, 1921) points out that crossing seems to increase early maturity in sheep and cattle.

Ritzman and Davenport (1931) write that, " So much has been said and written about the superiority of F_1 hybrids that heterosis has been loosely accepted as a corollary to crossing. There has been a tendency to laxness in defining by sufficiently clearcut classifications the traits in which improvement possessed by the hybrids manifests itself ". The detailed influence of crossbreeding on carcase quality is unknown. Crossbreeding experiments accompanied by detailed physical analyses of carcases, should do much to further test the commercial value of the practice.

The uses of crossbreeding in practice are to improve the deficiencies of one breed by crossing with another in which this character is well or (as possibly in the case of fat) overdeveloped. Hardy breeds under poor environmental conditions are crossed with early maturing and less hardy types to get the best of both in the offspring.

Conclusions.

1. The length of eye-muscle (A) lacks little in the breeds, especially at 21 months; the depth of eye-muscle (B) falls considerably short of the standard, but less at 21 months than at 9 months. The muscle of the ribs (X) should on the whole be deeper.

2. Length of bone is consistently selected against.

3. Most carcases are too fat. Only Blackfaced, Welsh, Cheviot and Ryeland × Cheviot are shown sufficiently lean at 9 months. At 21 months the first three and Suffolk × Southdown carry the right amount of fat.

4. At a constant weight (55 lb.) at 9 months, the shallowness of " eye " (B) remains one of the chief points of criticism. Few of the breeds treated are too fat, but bone is too long. At 21 months (constant weight 65 lb.) eye-muscle depth (B) and muscle on ribs (X) are too shallow. There is not much fault to find with fat depth over the " eye " (C). In fat over the ribs (Y) breed differences at 21 months become very marked. The cannonbone length is not a serious fault.

5. In muscle and bone (with age increase) those breeds with the greatest actual increase in measurement, have also the greatest percentage increase.

6. Fat growth is not yet absolutely controlled for all breeds fatten from 9 to 21 months. The leanest breeds have the greatest percentage increase in fat—they can afford to do so. The Welsh is unique in the proportionally great amount of fat added on the ribs. The percentage increase of fat on the ribs (Y) is greater than over the eye-muscle (C) for most breeds. The distribution of fat at C and Y is not similar in all breeds.

7. Muscle development in an animal within a breed follows the direction of bone development. At one age considerable differences in ratio of muscle to bone exists between breeds.

8. Under existing conditions quantity is paying better than quality; but those who produce qualiy, e.g. New Zealand, obtain an increasing demand for their product instead of a stationary or decreasing one.

9. The carcase qualties of the various breeds are described, and their shortcomings are pointed out.

10. In crossbreeding, the offspring approach the quantitative intermediate.

II.—Marbling.

Marbling in meat as seen by eye, pertains to the intramuscular fat laid down in the connective tissue between muscle bundles. It has been judged by eye and scored from 1 to 5; 1 equals most marbling, 5 equals least marbling. In most cases they were so graded by two different people: where their opinions differed by more than one grade the carcase was regraded.

(1) The Effect of Carcase-weight (Fatness) on Marbling.

Both at 9 months and 21 months with an increase in carcase-weight the marbling increases. This is proved by statistics for three breeds in Table XI and by averages for all breeds in Table III. An increase in marbling with an increase in carcase-weight is associated with the increase of fat above muscle (see Table VI a). In the winners (Table IV) where back fat at C remains very nearly the same thickness in spite of weight increase, the amount of marbling varies very little indeed.

(2) The Effect of Age on Marbling.

Marbling shows no significant difference of rate of increase with increase in carcase-weight between the two ages, but definitely increases as weight at one age increases. That age affects marbling to some extent is seen from a comparison of marbling between the two ages in the Southdown weight class averages (Table III). The fat measurements in the corresponding weight classes (50-59 lb. and 60-69 lb.) are less in 21 months than in 9 months, while the marbling average in spite of this is slightly better at 21 months. The difference in marbling due to age where back fat at C is kept constant, is seen from the following table:—

Legend (Southdown).	Constant Depth of Back Fat at C.	9 Months.		21 Months.	
		Measurement.	Carcase Weight.	Measurement.	Carcase Weight.
	m.m.		lb.		lb.
Marbling (M.)...............	9·56	2·80	56·04	2·56	66·40
Fat depth on ribs (Y.)......	9·65	14·35 m.m.	55·88	16·24 m.m.	67·53

[The averages for marbling were obtained from 11 Southdown individuals with C measurement 9 m.m. and 14 individuals with C measurement 10 m.m., in each of the 9 months old group and the 21 months old group, i.e. an average at each age from 25 individuals averaging the same in fatness. For fat depth on ribs (Y), 6 individuals at 9 m.m. and 11 individuals at 10 m.m. were taken at each age, i.e. an average from 17 individuals.]

With animals in the same condition of back fat the difference in marbling due to age is only 0·24 in favour of the older animal. In spite of having the same back fat measurement (C), the older animals were a little fatter as shown by the measurement of rib fat (Y).

The increase in marbling due to weight increase (chiefly fat) in Southdowns is however considerably greater than the increase due to age. Weight causes 1·52 increase for 30 lb. increase (35 to 65 lb.) at 9 months, and 1·56 for 40 lb. increase (55-95 lb.) at 21 months, whereas the difference due to age from averages of all exhibits is only 0·83. The slow fattening Blackfaced at 9 months for a weight increase of 30 lb. (35-65 lb.) increases 0·85 in marbling, whereas the age change (from general averages) is only 0·47.

(3) The Effect of Breed on Marbling.

At similar weights (Table III) breed differences are clearly marked. The Southdown for example at 9 months and about 45 lb. carcase-weight has an average of 3·02 compared with that of 4·27 for Blackfaced at the same age and weight. At 21 months and about 65 lb. the Southdown has 2·21 and the Blackfaced 4·11.

Table XVII (averages of all individuals) shows the differences in marbling due to breed. The distribution curves are given in Diagram XII. These averages are to some extent dependent upon the fatness of the carcase, but that there may be distinct breed differences independent of the thickness of subcutaneous fat is seen from a comparison at 9 months of the lean Welsh and the very fat Ryeland, the former being somewhat better marbled than the latter. The Kent, although considerably fatter than the Cheviot is not as well marbled. These breeds are of different types, but within a type differences exist; the Welsh, although it has a little thinner back fat than the Blackfaced at 9 months, is better marbled. The order of marbling in which the better represented breeds, Southdown, Hampshire, Suffolk, Welsh and Blackfaced come, is the recognised order in which they mature (as regards thickness of fat), that is, the early maturing breeds will commence marbling at a younger age than will the later maturing breeds. That carcase-weight, independent of fatness, does not influence marbling is evident from Table XVII.

At 21 months the breeds shown remain in practically the same order of marbling as in 9 months. The change in relative position of Suffolk, Cheviot and Welsh is unimportant as the differences between them at 21 months remain very small. The somewhat better marbling in the Welsh than in the Suffolk is in accordance with an age gain in fat percentage of 56 per cent. for the Welsh and 50 per cent. for the Suffolk.

In the crossbreds at 9 months old, with the exception of the Suffolk × Southdown, which equals the intermediate between the parent breeds, all crosses are better marbled than would be expected. All except Suffolk × Southdown, Southdown × Suffolk and Ryeland × Cheviot are also fatter than the intermediate between parents.

The two best marbled breeds (Southdown and Dorset Down) give the best marbled offspring when crossed. The Southdown × Suffolk, although carrying less fat than would be expected, has excellent marbling. Hammond (1932) states that the Suffolk is a good milker and that the milk supply of the dam is of the greatest importance for the growth of lambs in early life. In crossing with a Southdown ram, the good milking qualities of the Suffolk ewe will allow the comparatively small offspring to grow out quickly, and it seems possible that early maturity of the muscle will enhance the time at which fat is laid down within it. Neidig and Iddings (1919) find the Southdown a poor milker; the Suffolk × Southdown is fairly lean and not better marbled than would be expected. The Suffolk × Cheviot, both rather poorly marbled, give poorly marbled offspring. Similarly the Ryeland × Cheviot is poorly marbled.

Conclusions.

Marbling is influenced to some extent by age and is influenced by age sooner in an early maturing breed than in a late maturing breed. At the ages of 9 months and 21 months an increase in fatness at one age has more influence on marbling than has the age increase.

For accurate comparisons breeds should be compared at the same age and stage of fatness, but owing to the small numbers of individuals in some breeds and their natural variation in fatness, it was impossible to keep the thickness of fat constant. Marked breed differences do however appear to exist.

With our data the factors influencing marbling in order of importance, are fatness, breed and age. Under commercial conditions where the extremes of fatness are not so common, condition will be preceded by breed, and where a standard of fatness is closely adhered to, also by age.

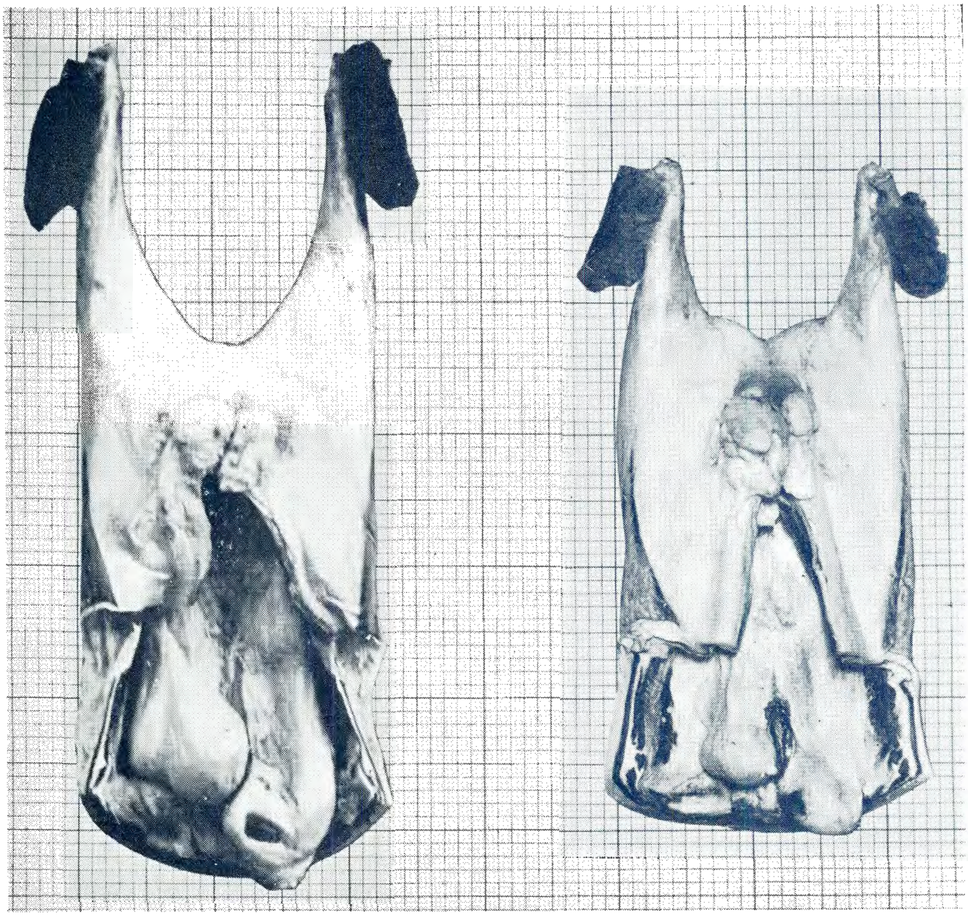
In mutton marbling has little effect upon price. The Blackfaced in spite of its poorer marbling makes the second highest price. The champion carcases average only 3·5.

Note.—The colour of mutton is important and should be as light and bright as possible, but the data collected up to date is insufficient to warrant any conclusions.

III.—A suggested Scale of Points for Judging Sheep Carcases.

Carcases at Smithfield show are judged entirely by eye. Certain points in the carcase can well be judged more easily and accurately by measurement. Such a system would create a more uniform standard from year to year and eliminate small fluctuations caused by personal preference of judges. It would form, too, a measure by which the breeders could be informed why and in how far their carcases failed to come up to the standard. A scale of points based upon the foregoing carcase measurements and intended for use under the present system of classification (age), has been tabulated. It may be readily adjusted to suit any changes in public taste (which, however, are not anticipated in the near future). Should show authorities be persuaded to allow carcases to be exhibited in weight classes instead of age classes, adjustment of the scale to suit the change can readily be effected. 75 marks are given for measurement (see below) and 25 marks for inspection. The shape of a good and a bad leg of mutton is illustrated by the accompanying figure. The points at which measurements are taken, have been illustrated on p. 384.

FIG. 3.



CARCASE POINTS.

Marks for Measurement.	*Maximum Marks.*
Thickness of Flesh (depth of eye-muscle = B.)	35
Thickness of Fat (over eye-muscle = C.)	30
Shortness of Cannon bone	10
	75
Marks for Inspection.	
Shape of leg	10
Colour of Meat	10
Meat on Ribs (= X.)	5
	25
TOTAL MARKS	100

Marks for Thickness of Flesh (depth of eye-muscle = B).
(Maximum marks = 35.)

Marks.	Carcase Weight (lb.)						
	30–39.	40–49.	50–59.	60–69.	70–79.	80–89.	90–99.
	mm.	mm.	mm.	mm. – and under –	mm.	mm.	mm.
1	20	22	24	25	26	28	30
5	21	23	25	26	27	29	31
9	22	24	26	27	28	30	32
12	23	25	27	28	29	31	33
14	24	26	28	29	30	32	34
16	25	27	29	30	31	33	35
18	26	28	30	31	32	34	36
20	27	29	31	32	33	35	37
22	28	30	32	33	34	36	38
24	29	31	33	34	35	37	39
26	30	32	34	35	36	38	40
28	31	33	35	36	37	39	41
30	32	34	36	37	38	40	42
32	33	35	37	38	39	41	43
35	34	36	38	39	40	42	44
			– and over –				

Marks for Thickness of Fat (over eye-muscle = C).
(Maximum marks = 30.)

Marks.	Carcase Weight (lb.).						
	30–39.	40–49.	50–59.	60–69.	70–79.	80–89.	90–99.
	mm.	m.	mm. – and under –	mm.	mm.	mm.	mm.
1	—	1	2	3	4	4	4
10	1	2	3	4	5	5	5
18	2	3	4	5	6	6	6
24	3	4	5	6	7	7	7
28	4	5	6	7	8	8	8
30	5	6	7	8	9	9	9
29	6	7	8	9	10	10	10
27	7	8	9	10	11	11	11
24	8	9	10	11	12	12	12
20	9	10	11	12	13	13	13
15	10	11	12	13	14	14	14
9	11	12	13	14	15	15	15
1	12	13	14	15	16	16	16
			– and over –				

Marks for Shortness of Cannonbone (maximum marks = 10).

Marks.	Carcase Weight (lb.).						
	30–39.	40–49.	50–59.	60–69.	70–79.	80–89.	90–99.
	mm.	mm.	mm.	mm.	mm.	mm.	mm.
			– and over –				
1	146	148	150	152	154	156	158
2	145 144 143	147 146 145	149 148 147	151 150 149	153 152 151	155 154 153	157 156 155
3	142 141 140	144 143 142	146 145 144	148 147 146	150 149 148	152 151 150	154 153 152
4	139 138 137	141 140 139	143 142 141	145 144 143	147 146 145	149 148 147	151 150 149
5	136 135 134	138 137 136	140 139 138	142 141 140	144 143 142	146 145 144	148 147 146
6	133 132 131	135 134 133	137 136 135	139 138 137	141 140 139	143 142 141	145 144 143
7	130 129 128 127	132 131 130 129	134 133 132 131	136 135 134 133	138 137 136 135	140 139 138 137	142 141 140 139
8	126 125 124 123	128 127 126 125	130 129 128 127	132 131 130 129	134 133 132 131	136 135 134 133	138 137 136 135
9	122 121 120 119	124 123 122 121	126 125 124 123	128 127 126 125	130 129 128 127	132 131 130 129	134 133 132 131
10	118	120	122	124	126	128	130
			– and under –				

BEEF.

Introduction.

Quality in beef involves a larger number of factors than quality in mutton. Where carcase proportions (muscle, bat and bone) are of chief importance in selling mutton, additional factors of equal importance operate in determining beef quality. Figures at our disposal on beef, except for marbling, deal exclusively with proportions. To complete the picture other factors will be briefly surveyed from the literature.

A beef carcase may be described in terms of conformation, finish and quality of meat. Best conformation involves short shanks and neck, deep and plump rounds, thick full loins and a relatively thick flank. Correct finish implies a smooth, sufficiently deep covering of firm white fat evenly distributed over most of the exterior surface of the carcase. Quality of the meat refers primarily to the structure of the meat, that is the size of muscle fibres and muscle bundles (texture), the amount and distribution of connective tissue per unit volume of meat, the amount and distribution of intramuscular fat (marbling), and the nature of the meat juices or extractives. These quality factors are closely associated with the tenderness and palatability of meat and, although of greater importance in beef than in mutton, are applicable to the latter in principle.

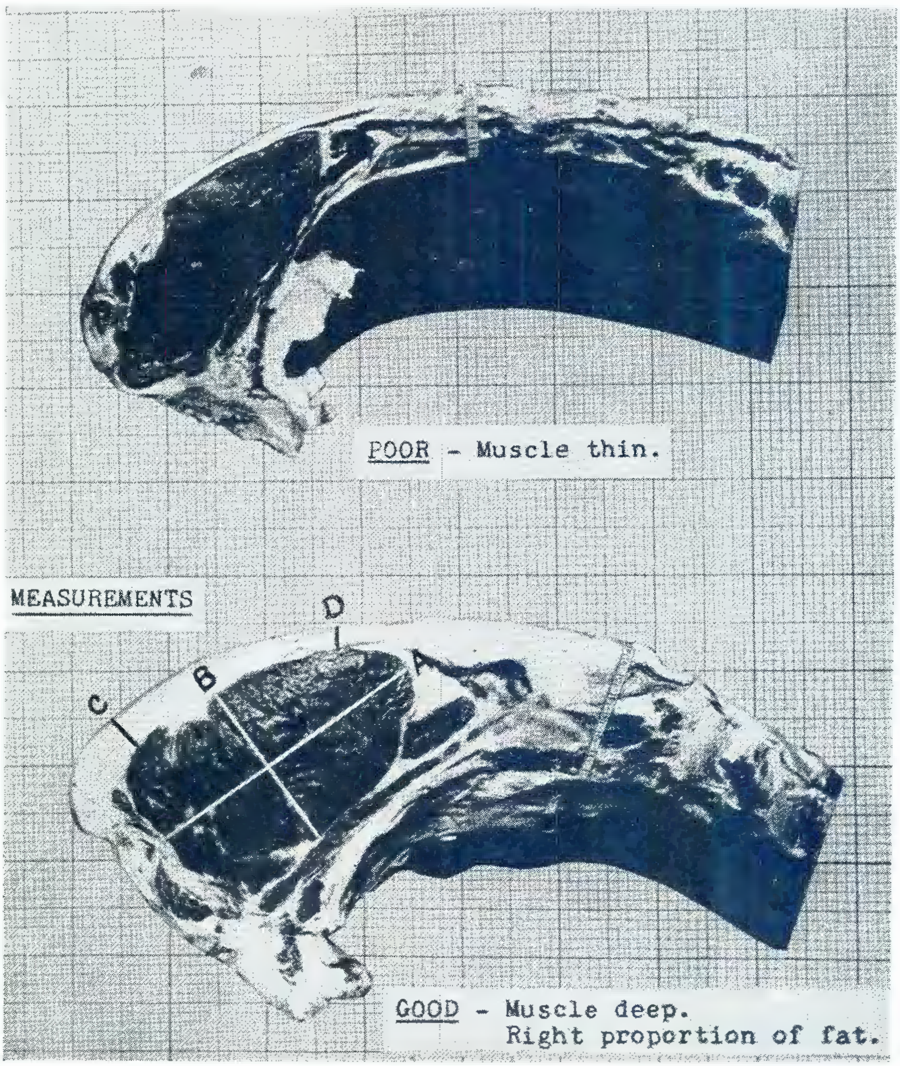
Beef carcases are subject to much greater cutting than mutton carcases, and because of this and the coarser nature of the meat, proportions of muscle, fat and bone in beef are of less importance to the consumer than in mutton where joints are retailed in relatively large units, for example a leg of mutton. The housewife purchases beef almost entirely according to the quality of the meat. To the retailer, who buys in bulk, both conformation and finish are extremely important in that the former tells him the percentage of highly priced cuts and the waste to be expected from bone, while the amount of finish is some indication of the extent of marbling in the meat (see page 454).

The main factors influencing carcase quality in general, i.e., conformation, finish and quality of the meat itself, are:—

Breed or Type.
Condition
Age.
Sex.
Feeding.
Management.
Exercise.
Methods of Slaughter.
Methods of Storage.

Quality as influenced by these may be expressed in terms of carcase proportions (muscle, fat and bone), texture of meat, colour of meat and fat, firmness of fat, marbling, flavour and nutritive value. Since the nutritive value of meat is not taken into account by the public except in the broader sense, it will be omitted from this discussion.

FIG. 4.



I.—Factors Influencing Carcase Proportions.

Breed.

The measurements taken on beef carcases are best described by means of the accompanying figure. Carcases were quartered behind the last rib, so exposing the eye-muscle of the last rib cut and the thickness of fat over it. All measurements from A to R (see below) are expressed in millimetres and M and K were judged by eye over a range of 5 points, 1 = most, 5 = least.

A = Length of eye-muscle (*longissimus dorsi*).

B = Depth of eye-muscle.

C = Thickness of fat over the end of the eye-muscle nearest the spine.

D = Thickness of fat (measured at thinnest part) lying over the end of the eye-muscle furthest from the spine.

R = Length of the *Radius Ulna.*

M = Marbling.

K = The sinewy kink (tendon) on the upper surface of the eye-muscle.

Weight = Carcase-weight in pounds.

Table XVIII gives the averages of the available breeds, the Standard Error of the means, the Coefficients of Variation, and the numbers of individuals constituting an average.

This table affords a comparison between 22 months' old steers of breeds of various types; two good beef breeds, Aberdeen Angus and Galloway, another beef breed, the North Devon, a dual purpose breed, the Red Poll, and a beef cross, Aberdeen Angus × Shorthorn. The Angus and the Galloway are much alike in measurements; the Devon is more thinly fleshed (B) and longer boned (R) than the Angus and Galloway. The Aberdeen Angus × Shorthorn has fairly good muscle but is as long in the bone as the Devon and in consequence of that and a somewhat thicker finish (D), is definitely heavier than the four pure breeds. The Red Poll and the Devon are much alike.

Exaggerated breed differences (from the meat standpoint) are apparent between dairy and beef breeds, the latter being more compact, thicker fleshed and shorter legged than the latter (Fuller *et al*, 1929). It has been noted that a well-bred beef animal tends to increase external fat rather than internal fat (Edinger, 1925 and Wisc. Agr. Expt. Sta. Ann. Rep. 1927-28). Hankins and Burk (1932) from an analysis of data from 2,073 cattle, find a fairly close correlation ($+\cdot 69 \pm \cdot 008$) between feeder grade (which to some extent is a criterion of breeding) and carcase grade.

Table XIX gives average measurements of the winning carcases (1st and 2nd Prizes). A suitable depth of fat over the " eye " at C is about 20 m.m. (4/5 inch) and at D about 12 m.m. (½ inch). It will be seen from a comparison with Table XVIII that over-fatness is no problem in show beef. In the yearling class there has been selection for fatter animals. Two-year olds will attain the mark readily with reasonable feeding, while in yearlings it is only under the most intensive feeding conditions and with good beef animals that the required fatness will be reached. The great improvement in feeding in the last years is apparent from the following measurements of prize winning yearlings:

Period.	*No. of Individuals.*	*A.* mm.	*B.* mm.	*C.* mm.	*D.* mm.	*Weight.* lb.
1921–1923	6	125·7	60·2	13·7	6·3	449·0
1930–1932	6	135·0	70·7	19·3	9·8	635·7

Fullness of muscle is consistently selected for. In the Aberdeen Angus and Galloway there is little fault to find with the muscle and bone development. The Red Poll (22 months), the Devon and Aberdeen Angus × Shorthorn are lacking in muscle development and are too long in the bone.

It may be mentioned here that the tendon or " kink " on the upper surface of the eye-muscle is not influenced significantly in our figures by either breed, age or sex.

In the last 14 years 10 of the 14 championships were awarded to Galloway carcases, the other 4 going to Aberdeen Angus.

Condition.

The condition of the animal has a considerable influence on the proportion of muscle, fat and bone in the carcase; the distribution of the fat influences the eye judgment of the carcase. Townbridge, Moulton and Haigh (1919) found that as animals fattened the skeleton decreased from 19 per cent. to nearly 10 per cent., muscle decreased from 44 per cent. to 33 per cent., while fat increased from 8 per cent. to 28 per cent. Foster and Miller (1933) and Edinger (1925) conclude the same. The latter states that with increase in carcase weight the weight of bone and muscle increased, but not as rapidly as the weight of fat. (The amount and rate of increase of the tissues depend much upon the age of the animal and/or its previous plane of nutrition as will be shown subsequently.) In all the wholesale cuts animals in the highest condition gave the highest percentage of the more valuable cuts (Edinger, 1925, and Trowbridge, Moulton and Haigh, 1919), that is the rear half of the animal improved more than the fore. As regards the distribution of fat, the hind part of the animal (loin, rump and rounds) adds fat more rapidly than the fore part (chuck) which is the earlier developing.

Age.

Age very definitely affects the proportions of the carcase. Hammond (1932) has shown how, as the animal increases in age on a normal plane of nutrition, the long-legged big-headed short shallow-bodied youngster gradually changes shape until at maturity the legs are proportionally short, the head small and the body long and deep as compared with the newly born.

Table XX presents the increase and percentage increase of the measurements and the significance of the difference due to age increase. In the Aberdeen Angus steers all measurements increase significantly from 15 to 22 months; in heifers increase in the length of the muscle (A) is insignificant. This may be due to earlier maturity of the heifer or to the fact that small numbers at 15 months (5 individuals) caused statistical insignificance. It is unlikely that there is no increase, however small it may be, for Hogan (1929) has shown that the length of the growth period (of bone) of normal beef steers is about six years. In steers from 22 to 33 months old only the depth of muscle (B) and bone increased significantly. Had the state of fatness not been controlled there would undoubtedly have been also an increase in fat measurements. Angus heifers show no significant increase from 22 to 33 months in any measurement. Since there is a weight increase this result is absurd; but the increase in weight of 16·2 per cent. is comparatively small and the increase split up and accorded to the various parts producing it leaves the measurement of each part with an increase probably insufficiently large to appear statistically significant, especially with the small number of animals at our disposal.

No Galloways are shown in the under 15 months class, for the conditions under which the young animals are kept do not allow of rapid maturity of the carcase and have gained for the breed the reputation of being slow to mature. As a result there is considerable growth from 22 to 33 months, so that all increases are significant. Fat at D is doubtful because of great individual variation in this measurement. Heifers have insignificant fat increases as condition has to be strictly controlled on account of the female tending to fatten more rapidly than the male (see p. 437). The Red Poll steers increase significantly for all measurments from 15 to 22 months. (Heifers do not compete in carcase competitions, for being dual purpose they are kept for milk production.)

Over a period of fourteen years commencing in 1921, one champion was in the under 15 months class (1933), nine were in the 22 months class, and four in the 33 months class.

In order to see how the proportions of fat, muscle and bone changed with increasing age, ratios between these measurements were worked out for the different ages of steer and heifer averages available. Table XXI gives the results. Muscle and fat throughout increase with age more than bone; fat increases more than muscle from 15 to 22 months only, as at 22 months the animal reaches an optimum fatness and is not allowed to fatten much further. The small increase in fat is scarcely sufficient to offset bone growth and in the Angus and Galloway is insufficient to offset muscular growth. Muscle growth (Angus, $\frac{A \times B}{\text{Bone}}$) is considerably greater in the younger animal (15 to 22 months) than in the older (22 to 33 months). The edible portion of the carcase (muscle and fat) in relation to bone, increases with age. Wood and Newman (1928) found that bone in the round of a fat animal at 19 months was 18·6 per cent., whereas at 34 months it had decreased to 10 per cent. Our figures with sheep and those of Hammond's (1932) show that gains made by older animals are very largely due to fat.

Growth of the various tissues (muscle, fat and bone) may be considered as a series of waves, which partly overlap but have clear peaks where they reach their maximum growth rate. Bone reaches its peak first and is followed by muscle development, which on abating, allows fat the nutrition which bone and muscle each in their turn had claimed. The point of practical importance to the producer is to know how best to increase the rate of muscle growth and to know at what point it has abated sufficiently to allow the animal to make the best use of a fattening ration. In other words we do not yet know how to suit rations to the growth requirements of animals at various stages of their development. The modern demand for light carcases has increased the urgency of adding fat early in the life of the animal. This may be accomplished by feeding (see Table, p. 434) and breeding. Breeding, while forcing the peaks of the growth curves closer together also tends to decrease the development of bone and muscle, so giving a smaller, lighter and more " chuffy " carcase. Within a given time this type of animal will not produce the carcase volume of the rangier type, but will give a carcase of higher quality at a lighter weight, which is what is wanted. The evolution and production of the ideal type can however, only proceed and be successful in an optimum environ - ment, and these conditions, while promoting development of an ideal carcase unfortunately do not seem to increase or maintain the constitution of the animal, so that on a lower plane of nutrition such as provided by range conditions, breeds with a potentially perfect shape are liable to " go to pieces ", while the somewhat rangier and slower maturing types commonly associated with a rugged constitution, thrive better. The quality-constitution problem has been partly solved by judicious crossing of the two types.

To return to the proportions of the carcase, Helser (1930) found an insignificant difference in the proportion of cuts due to age. Proportions of lean to fat in finished steers of different ages was very uniform. This does not agree entirely with our data, but equalisation was probably due to the fact that calves, yearlings and two-year-olds all started as " feeders " and all received the same ration. Gramlich (1928) shows that to produce 100 lb. of gain, calves needed 529 lb. of maize, yearlings 702 lb., two-year-olds 798 lb., and three-year-olds 836 lb. Thalman's (1932) figures agree in principle. Bull *et al* (Illinois Agr. Expt. St. Rept. 1931-32) found that yearling carcases graded somewhat better in conformation than calves and were fatter. Potter, Withycombe and Edwards (1931) in fattening calves and yearlings (12 and 24 months old respectively at sale), conclude that calves make good gains in weight but the degree of finish they will acquire is not as dependable as that of a more mature animal; further, that profitable fattening of calves and yearlings requires rather concentrated rations and close attention to every detail. Their findings stress the point that fat is not easily laid on by the younger animal. The cost of production would be to some extent offset by the smaller amount of food necessary to produce gains in the younger animal. Thalman puts the case for the cattle feeder: " Regardless of quality, the feed required to produce a pound of gain, and therefore the cost, increases as the age of the animal increases. Yearlings and calves make efficient gains over much longer periods and therefore are not so expensive to hold. Furthermore, there is a much greater and more flexible demand for the lighter weight cattle, which results in a more stable market for them ". The latter statement holds for the Central Meat Markets of London. As Hammond and Murray (1934) have shown, the lighter carcases in times of bad prices, drop less in price than heavier ones.

Sex.

A widespread belief exists among butchers in U.S.A. that heifers are inferior to steers, chiefly because they are supposed to be wasty cutters. In England, on the contrary, there is a considerable demand for heifer beef and many butchers look out for heifers because of the better finish they are expected to carry. Producers in Northumberland, because heifers finish earlier than steers, buy up nothing but heifer stores to get them off quickly on the early grass of that region.

The difference between steers and heifers are indicated in Table XXII. On the whole sex differences, except for length of muscle (A) and bone (R) are insignificant. As has been pointed out with sheep, of those taken these two measurements are the first to mature and are correlated. The same seems to hold for cattle. Small numbers and considerable individual variation in the later maturing measurements (B, C and D) prohibit statistically significant differences, but definite trends are nevertheless obvious. The muscle measurements A and B are consistently greater in the steer than in the heifer, and a greater difference seems to exist between sexes in the length of the eye-muscle (A) than in depth of muscle (B). Differences in the Angus at 15 months and 33 months are uncertain because of the small numbers compared; but because even the weight differences at 15 months are insignificant, it seems as if sex differences at this age are of no importance. In general the females are fatter than the males from 22 months on, while weight differences due to sex, in the Aberdeen Angus anyway, seem to increase as age increases, the male becoming progressively heavier than the female. This is probably due to the earlier maturing female making less gains in muscle than the steer, for fat onput is controlled, while muscle growth continues normally. The weight differences noted above are in agreement with Hammond's (1920) results on cattle.

Differences in relation of the measurements of steer to heifer are further evident from ratios in Table XXI. The ratio of muscle to bone $\frac{(A \times B)}{R}$ remains nearly the same for the steer and heifer at different ages. The fat to bone ratio $\frac{(C+D)}{R}$ in the young animal under 15 months old shows no sex differences, but from then on the female has the higher ratio. Similarly in the fat to muscle ratio $\frac{(C)}{B}$ the young animals show very small differences, but from 22 months on heifers have a higher proportion of fat than steers. These results lead one to conclude that proportions of muscle to bone are the same in steer and heifer carcases, but that at the same age from the yearlings on, heifers will be fatter than steers. The following percentage figures of the physical analysis of the rib cuts from two steers and two heifers are taken from an Annual Report of the Illinois Agricultural Experiment Station (1926-27).

Tissue.	Steer.	Steer.	Heifer.	Heifer.
Lean	68·12	65·20	57·96	58·70
Fat	6·06	7·31	15·03	12·43
Bone	23·88	24·01	22·04	25·19

It is agreed that the heifer reaches a given state of fatness sooner than the steer (Illinois Agr. St. Rept., 1926-27; Trowbridge and Moffat, 1932; Bull et al., 1930; Hankins, 1932), that is the female matures more early than the male, and with an early cessation of bone and muscle growth nutriment is available for fat onput (Hammond, 1932). The ratio of fat to lean in steers and heifers remains about the same up to approximately 625 lb. live weight and thence rises in favour of the heifer (Hankins, 1932; Helser et al, 1932). In rib cut analyses, at a similar killing weight for steers and heifers, heifers yielded a smaller percentage of lean and a larger percentage of fat than steers (Illinois Agr. Expt. St. Rept., 1926-27; Bull et al, 1930; Foster et al, 1933). Evidence on the proportions of the various cuts in steer and heifer carcases is somewhat conflicting. On the one hand no differences in percentages of round, rump, loin, ribs and chuck were found attributable to sex and no difference in the percentage of wholesale cuts (Bull et al., 1930; Foster et al., 1933). Others find a smaller percentage of hindquarters, heavier rounds, lighter loins and lighter flanks in steers, but no difference in the percentage of more valuable cuts (Gramlich and Thalman, 1930; Illinois Agr. Expt. St. Rept., 1926-27). Sex differences in carcase proportions will only become marked as sexual maturity is approached in the heifer; but more evidence is necessary before concluding what exactly these differences are, and to what extent steers and heifers differ at various ages. Davis (1932) in describing the differences in conformation between yearling steers and heifers states that sex characteristics have not developed to a point at which any appreciable differences in market value are recognised. The optimum slaughter weight recommended for heifers in U.S.A. is 700-750 lb., for steers about 850 lb (Foster and Miller, 1933; Hankins, 1932; Thalman, 1932). Our findings on carcase proportions considered in conjunction with those of Hammond and Murray (1934) on carcase prices, lead to the conclusion that while baby beef, if well finished, will make the highest price per stone on Smithfield markets, a carcase weighing 650 lb. will still find a ready sale; further, that when steers and heifers are approximately equally fat, no price discrimination exists against heifers.

Feeding.

The amount of feed and its nature are of importance in affecting the proportions of an animal at any one age. A considerable amount is known of the effect of various planes of nutrition upon external body proportions, and the weights and chemical composition of the body parts, but little is known of the way proportions of muscle fat and bone are affected as regards linear measurements, or what the different ratios and kinds of protein and carbohydrates in the diet have upon their development.

Beginning with fat yearling steers, Trowbridge, Moulton and Haigh (1918) found that the growth of the skeleton has primary demand on nutrition and persists even under very adverse conditions. On a submaintenance ration, nutrition for maintenance of life is derived from external fat, internal fat, intramuscular fat, body proteins and lastly, when very much underfed, from fat in the bones themselves. Henseler (1914) and Waters (1908) found that feeding affects proportional development considerably. The latter states that scanty feeding, while not materially hindering the growth in height, causes retardation of the middle width of the body. Hogan (1929) found that a low plane of nutrition lengthened the growing period, but that only a low plane of nutrition for the first three or four years tended to reduce mature size (height). Both severity and length of underfeeding affected mature size. Watson and Hunter (1906) found that an unsuitable diet used in the growing period caused a permanent stunting of muscle growth. The Nebraska Experiment Station (1931) reports that lambs fed on a high protein ration before and after weaning made slightly better gains than on a low protein mixture. Hammond (1934) considers that retarded growth in the young pig has an adverse affect on the quantity of muscular tissue eventually laid down. In beef production it is a well known saying that calves should never lose their " baby flesh ". With cattle Moulton (1920) has shown that on a subnormal diet muscle fibres become smaller in diameter, which means a loss in thickness of muscle. Callow (1935) states that a deficiency in the quantity of protein in the diet, or the excessive use of an incomplete protein like that in maize, retards growth. Mitchell, Hamilton and Smuts (Illinois Agr. Expt. Stn. Rept., 1931-32) have shown to what extent some of the most common cereals and meat proteins are deficient in certain amino acids. We do not yet understand the causes of badly developed muscular tissue and studies are needed to determine what ratios and amounts of amino acids in the diet enable optimum muscle growth, and how the balance of protein to carbohydrate should be altered in relation to the growth of animals of various ages and different species. Mitchell, Hamilton and Kammlade (Illinois Agr. Expt. Stn. Rept., 1931-32) have commenced investigations in this field. The beneficial effect of good feeding on carcase proportions has been demonstrated by Foster (1933) and Trowbridge (1931).

Exercise.

The effect of exertion on the condition of an animal is well-known. Bone growth is not known to be in any way affected by exercise or lack of it. Among pig producers it is maintained that exercise increases the development of muscle, but there is reason to believe that the result is more closely associated with the better health of exercised animals. Where exercise was increased to work, Mitchell and Hamilton (1933) found that after walking steers 1,181 miles in 381 working hours at 3·1 miles per hour, the moisture content of the muscles was somewhat lowered, but that the nitrogen content of the fat free dry matter was not appreciably altered. Unfortunately no histological studies were made. Hammond (1932) inclines to the opinion that exercise increases the diameter of the muscle fibre. It seems possible that the nature of the exercise influences the size of muscles more than the amount; the slow, steady strain exerted by weight lifters tends to swell the size of muscles, the swift motion practised by runners has no such effect. Breed is of far greater importance to muscular development than exercise; typical dairy animals, although obtaining the same amount of exercise as beef breeds in Great Britain, never develop the same bulge of meat.

II.—Factors Influencing the Texture and Tenderness of Meat.

Factors except Storage.

The texture of meat is thought to be closely associated with toughness, and up to date it is believed that in two similar cuts the finer grained meat will eat the more tender. Texture is largely dependent upon the number and development of fibres in a muscle bundle, tenderness upon the amount and distribution of connective tissue (collagen and elastin) in the meat.

Hammond (1932) in setting forth his results on texture has cited many authorities. Concensus of opinion goes to show that fibre size increases with age, exercise and nutrition; the male has larger fibres than the female, the castrated male being approximately intermediate. The fatness of the animal as such affects fibre size very little, although a connection between fatness and muscular nutrition probably accounts for the findings of Robertson and Baker (1933) that muscle fibres of full-fed animals were greatest in diameter, those of rough-fed steers smallest, and those of half-fed steers intermediate. Opinions differ regarding breed differences, some fiinding small differences, others comparatively large ones. Differences have been noted between dairy and beef breeds, but none between the beef breeds themselves.

Hammond (1932) has shown that in the sheep muscles with the greatest post-natal growth have the largest fibre diameter and hence the largest muscle bundles; muscle bundles in the wether are larger than those in ewes; breed differences showed that smaller animals have smaller grain, but not in proportion to the differences in body weight. Adametz (1888) in examining breeds of cattle found no correlation between size of fibre and size of muscle bundle.

Lehmann (1907) states that the toughness of meat is largely dependent upon the amount of connective tissue fibres contained in it. His view is substantiated by Mitchell and Hamilton (Illinois Agr. Expt. Stn. Report., 1927-28) who found that the less tender cuts such as those from the shoulder, contained more collagen than the more tender ones from the rib and tenderloin for example. But toughness, in comparing similar cuts from animals of the same age and in the same condition, may be also a function of the distribution of the connective tissue. In masticating, the effect of toughness is probably due largely to the unwillingness with which muscle bundles part on maceration by the teeth. Given the same percentage of connective tissue in two pieces of meat of equal volume, one piece being fine grained and the other coarse grained, the former is likely to be the more tender, because in it the given amount of connective tissue present is spread over a large area and is thus thinner than in the coarse grained meat, and the structure more easily broken down. This theory assumes an inherent difference in size of muscle bundles which is supported by the results of Adametz (1888), Hall (1910) and Helser (1923). Hammond (1932) finds a correlation between tenderness and smallness of fibre of $+0 \cdot 71$, and between tenderness and smallness of muscle bundle of $+0 \cdot 33$. Moran and Smith (1929) also find a correlation between grain of meat and tenderness.

In young animals and over a small age range, Mitchell and Hamilton (Illinois Agr. Expt. Stn. Rept., 1927-28) found no age or sex differences (between steers and heifers) in collagen content of the meat. It is interesting to note that although generally accepted that meat from old lean animals is tough, the meat from a " canner " cow contained less collagen than meat of a choice two-year-old steer. Our knowledge of the causes of tough meat is incomplete. With mechanical tests Helser (1930) found calves meat tougher than that of older animals; between sexes he found no difference in quality (1932). With fattening the collagen content increased as well as the inter-fasicular spaces. The meat of fattened animals is nevertheless known to be more tender than lean meat. It is possible that with the laying down of fat in the connective tissue, the collagen fibres are forced apart and split up. so becoming more friable on mastication. This would offset the effect of toughness caused by an increase of connective tissue with age. But evidence on texture and connective tissue, their interrelation and the effect on toughness of meat is still scarce and inconclusive.

From the viewpoint of the range cattle farmer it is interesting to note the results of Mitchell and Hamilton (1933) that the effect of exercise (walking) was to decrease the collagen percentage of the meat and increase its tenderness. Leighton and Douglas (1910) on the other hand state that the effect of exercise is to increase the muscle sarcolemma and the denseness of the connective tissue holding the fibres together, a condition which would make for greater toughness. This probably occurs when exercise takes the form of draught. Black, Warner and Wilson (1931) find grass-fed beef a little tougher than beef fed a supplementary grain ration.

Storage.

The tenderness of meat is greatly improved by conditioning or ripening (Moran and Smith, 1929; Hoagland *et al* 1917; Lehmann *et al*, 1907). The increase in tenderness which occurs when meat is hung is due to chemical change in the proteins of the muscle substance and the protein called collagen, which is the main constituent of the muscular connective tissue fibres. Both changes are due in the first instance to the lactic acid produced in the muscle fibres from the glycogen content of the meat. Firstly the stiffening and shortening of the muscle fibres (*rigor mortis*) caused by a post-mortem coagulation, i.e. a decreased solubility of the proteins within them, is resolved by the action of the acid changing the protein into more soluble forms. Some few days after death at a time depending mainly upon temperature, rigor is completely resolved and the further development of tenderness is due mainly to the softening and swelling of the collagen by the action of lactic acid on it. When hanging is long continued (beyond about 30 days), the additional hydrolytic action of the intrinsic ferments (autolysis) takes a hand, but in commercial hanging practice of anything up to 14 days, this latter reaction is of no importance (Moran and Smith, 1929). The average conditions for successful hanging are 10-12 days at 36-38° F. and about 85 per cent. relative humidity, but good results have been obtained over 17 days at temperatures of 32°-41° F. (Moran, 1930). The underlying object is to keep temperatures and relative humidity just low enough in the storage chambers to prevent attack by micro-organisms. The coarser cuts of beef are found to be improved to a greater extent by hanging than the better cuts.

In transportation over long distances the structure of meat may be influenced by necessary conditions of storage. Where meat is slowly frozen at −10° C., ice crystals form in between the muscle fibres. On thawing rapidly the moisture is not reabsorbed by the fibres and a drip draining away a reddish fluid containing salts, proteins and muscle pigments, occurs, and the meat is left flabby and unattractive (Moran, 1930). With very gradual thawing (which is difficult under commercial conditions) the fibres are given a chance to reabsorb moisture, drip is lessened and the appearance of the meat maintained. The difficulty of drip may be overcome in small joints such as distributed in cartons by United States packing houses by rapid freezing (−20° C.), in which case ice crystals are formed within the fibre thus preventing drip on thawing (Moran, 1929). As the penetration of this effect is only 2½ inches (Moran, 1930), it is impracticable where larger joints are shipped. In tests (Lampitt *et al*, 1933) the slow freezing method gave slightly greater tenderness than rapid freezing, particularly in the case of mutton where tenderness and texture varied together fairly closely in the same direction. Considering whole carcases, mutton and lamb because of smallness, freeze through more rapidly than beef, and hence are less liable to deterioration by drip than beef.

Where transport takes not much more than 25 days, chilling gives excellent results (Moran, 1930), the principle being to hold the meat just above freezing point (−1° C. or 30·2° F.). Actually the meat is shipped one or two degrees lower to reduce mould growth and becomes frozen on the outer surface, but joints on the whole are rendered far less unattractive by chilling than by freezing. Comparing methods of freezing Moran and Smith (1929) found that freezing had no ill effects on the palatability of the meat. The experiment was carried out however with prime beef and under ideal conditions of thawing etc. and held in storage for only a few days, and it is still uncertain how far the decreasing demand for frozen beef is affected by quality as against the " off " appearance due to drip.

Recent investigations into the possibilities of gas storage in carbon dioxide (Moran, 1934) have rendered practical results which increase the life of chilled meat 100 per cent., and make it possible for far lying countries such as Australia to ship beef to the English market by means of the chilling system.

III.—Factors Influencing the Colour of Meat.

Hammond (1932) states and quotes extensively to show that the colour of muscle varies with its content of haemoglobin. Brooks (1929) and Heiss and Hohler (1933) have shown that the intensity of muscle colour depends chiefly on its haemoglobin concentration. The public accept the colour of meat as a guide to quality. Old beef and bull beef have long been associated with dark colour and toughness, and although dark meat in a young animal may make excellent eating, the fact is not generally recognized. Beef is unfortunately displayed in most retail shops in relatively small joints, and it is not always possible for the public to judge from what class of animal the meat has been cut, so that a light colour offers some margin of safety.

Breed.

Colour differences due to breed have been noted (Hammond, 1932; Hall, 1910; Helser, 1923; Adametz, 1888; Kansas Agr. Expt. Stn., 1926-28). Experiments at Wisconsin University (Wisc. Agr. Expt. Stn. Rept., 1928-29) on the other hand disclose no colour differences between breeds as widely divergent as the Angus and Holstein. From observations at shows, packing houses and meat markets we are inclined to believe that individual variation within breeds is of far greater importance than any small breed differences which may exist.

Condition.

The animals in better condition are mostly found to have lighter coloured meat (Trowbridge *et al*, 1918; Bull *et al*, 1930; Leighton *et al*, 1930); other workers (Kansas Agr. Expt Stn, Rept., 1926-28) tentatively advance results showing that a better finish renders beef darker at the time of cutting. Had the meat been allowed to brighten normally, different results might have been obtained. Personal observations incline to the opinion that well finished animals have the best coloured meat.

Age.

Hammond (1932) found that in lambs all muscle fibres were of the same colour. By 5 months they had differentiated into light and dark fibres, the latter increasing in intensity of colour by the age of 11 months. How muscles darken with age has been well illustrated by Schmid (1929) in corresponding joints from calves, baby beeflings and steers. Other workers (Bull *et al*, 1930; Helser, 1930, De Lisle, 1930; Foster, 1928; Ill. Agr. Expt. Stn. Rept. 1931-32) obtain essentially the same results. Beef reaches its optimum colour between one and two years of age.

Sex.

Hall (1910) and Leighton and Douglas (1910) agree that the flesh of steers is lighter in colour than that of bulls. Sustschowa (1910) has shown that castration diminishes the haemoglobin and erythrocyte content of the blood. McCay (1931) with over 1,000 determinations has shown that the blood of bulls has a higher haemoglobin content than the blood of cows. No difference in colour was found between steers and heifers (Bull *et al*, 1930).

Feeding.

Hammond (1932) states that the flesh of calves fed on milk or potatoes (deficient in iron) is particularly white in colour, while in those which have a mixed diet (with oatmeal, containing iron) it is much darker. Although the number of steers is too small to establish the point definitely, Bull *et al* (Illinois Rept., 1928-29) report that barley gave a lighter beef (haemoglobin content 0·291) than maize-fed steers (haemoglobin content 0·325). The Kansas Station (Rept. 1928-30) reports the muscle haemoglobin content of grass-fed beef to be 0·4584, maize and grass 0·4164, and dry lot 0·3960, but states that grass-fed beef was nevertheless of excellent colour. Longwell (1930) found the colour of grass-fed beef in no way inferior to grain-fed animals when the degree of finish was similar. Black (1931) finds grass-fed beef slightly darker in colour but with greater variation among individuals than among test lots. Small colour differences due to the nature of the feed seem to be commercially unimportant where animals are in similar condition.

Management.

It is generally believed that the colour of meat varies with the method of killing adopted as this may greatly influence the thoroughness of bleeding. Hall (1910) states that animals killed after much exercise or in a feverish condition due to long shipment, pregnancy, or excitement at slaughter, will have the capillaries dilated and are more difficult to bleed. Experiments by Bull *et al* (Illinois Rept. 1928-29, 1929-30) showed no differences in colour or haemoglobin content of meat between steers bled immediately after stunning, deferred bleeding for 5 minutes, and koshering. Packing houses in the United States (1934) find stunning the most suitable method of producing insensibility before bleeding; they state that stunning by electrical shock is not so suitable in that it is liable to produce blood-shot meat. Sir Frederick Hobday (Lecture to the Cambridge University Agricultural Society) found, however, that in over two million pigs stunned by this method at an abattoir in Austria, not one case of flashed pork appeared.

Exercise.

Hammond (1932) believes that the amount of haemoglobin (and consequently colour) in a muscle varies directly with the amount and duration of work it is capable of doing. Lehmann (1904) found in birds that the muscles most used contained 3·7 per cent. haemoglobin whereas the least used contained only 1 to 1·6 per cent. Whipple (1926) criticises Lehmann's method as inaccurate, and attempts to prove the principle himself, not in the same animal, but between animals. Unfortunately his exercise was unmeasured, his breeds of dogs entirely different and his subjects somewhat few in number. His work, however, presents a strong argument in favour of the increase of muscle haemoglobin with exercise. Mitchell states that exercise is known to affect the colour of the lean of laboratory animals (Illinois Rept., 1928-29), but in steers walked 1,181 miles on the level, 8·8 miles per day at 3·1 miles per hour, only the *triceps brachii* muscle became a darker red (Illinois Rept. 1929-30). Based on the above it seems improbable that exercise incurred by normal range grazing would affect the colour of beef adversely.

Storage.

Colour changes in meat during storage may be of a chemical or physical nature, or both, depending upon conditions of temperature, humidity and sanitation in the place of storage.

When meat is freshly cut, the colour is normally a dull purple-red (reduced haemoglobin) which on exposure to air rapidly becomes pinker and brighter (oxyhaemoglobin) due to the combination of reduced haemoglobin with oxygen. Depending upon temperature and humidity of the air, a gradual colour change takes place due to drying of the meat surface, the meat becoming progressively darker until it is almost black. On drying, a somewhat gel-like superficial layer is formed (the thickness depending on the extent of drying) which differs from the tissues beneath by an increased rigidity and transparency. This change of transparency increases the depth of penetration of light before reflection, and this, together with the increased concentration of pigment, leads to an increase in the depth of colour (Brooks, 1929).

In order to determine the error introduced by this factor on colour readings of meat taken at the Smithfield shows, an experiment was carried out as nearly as possible under Smithfield conditions to determine the rate of these colour changes in beef. Steers were slaughtered in the afternoon, broken the following morning, and the first rib cut removed from one side, the colour reading of the fresh cut meat taken and the meat then hung with all despatch in a chamber at 5° C. and approximately 65 per cent. relative humidity. Owing to a rather rapid air circulation in the chamber caused by a revolving electric fan on the floor, it was deemed advisable to hang a tubular cardboard sheath, open at either end, around the meat to prevent undue evaporation of moisture. Colour readings were made with Hammond's modification of the Munsell beef colour scale. The blads of the scale are of colour-sprayed celluloid and numbers increase in order of darkness, the highest numbers being the darkest blads. To extend beyond the darkest blad (No. 12) an extension scale was drawn up with oil paints on paper. The entire scale proved satisfactory. Lighting was by means of an Osram 100 watt " daylight " (cobalt blue) bulb held at constant distance and angle to eye from the surface of the meat. Sample 1 was from a 3-year-old Shorthorn-cross steer, samples 2 and 3 from 2-year-old Shorthorn-cross steers. All samples were poorly marbled and of fine texture, giving a very homogeneous surface which facilitated colour readings.

Diagram XIII A depicts the brightening curves. Irregularity of the curves for 3a and 3b is to some extent due to the difficulty of registering small colour differences not in the scale, by eye. The curve of sample 1 is typical. Rapid brightening occurs within the first half hour, slowing down progressively until about 5 hours after cutting, then stationary for a period of 5 hours, after which the colour gradually deepens. Sample 2a gave much the same type of curve. After hanging 2a for 7 days the darkened area was sliced off and readings commenced on the fresh cut surface (sample 2b). No explanation is offered for the peculiar behaviour of this meat. The interior had gone a light purply pink colour which after darkening to about the lightest shade the fresh meat (sample 2a) had reached on brightening, dropped to starting point, and at 2 hours already commenced darkening rather more rapidly than normally. Sample 3 was allowed to brighten for 2 hours, when it was divided in two and readings commenced on the fresh cut surfaces. One half (sample 3a) was covered like the rest of the samples had been, the other (sample 3b) was hung in the open to see what effect more rapid drying off of surface moisture had on colour change. The meat of 3a and 3b took somewhat longer to reach maximum brightness than the fresher meat (sample 3). The enclosed portion (3a) brightened a little more than the exposed half (3b).

When darkening set in, the curves of 3a and 3b ran approximately parallel. Diagram XIII B represents darkening over a period of days. Samples 3a and 3b which were allowed to hang for 16 days, seemed to have attained their maximum darkness, being almost black. At the 4th day of hanging the surface of the uncovered sample was quite dry and hard, while that of the covered sample was still pliable and damp. On the following day slime was visible on this sample and it gradually developed a rather unpleasant musty smell. The uncovered sample remained sweet until removal, when both samples had a growth of fine whiskers on their surface. The drying off of the surface made a considerable difference to the keeping qualities of the meat in that it prevented the attack of micro-organisms. Brooks (1929) found that a sample of meat had turned very dark red after 24 hours' exposure at normal room temperature and humidity (figures unstated). At a temperature of about 19° C. and 57 per cent. relative humidity we found that a sample taken from beef killed two days previous reached its maximum brightness (changing from grade 12·0 to 10·5) in 20 minutes, remained steady for 3 hours and then gradually commenced darkening so that at the end of 24 hours it had again reached the same colour as when freshly cut (grade 12).

The Kansas Station (Rept. 1926-28) report that the brightening process is most rapid during the first 30 minutes after cutting, but continues for about 3 hours, after which there is a tendency for the cuts to become darker. Helser (1930) found meat of animals of different ages and in different condition at one age to brighten only one grade on the Munsell scale, but does not state conditions of temperature and humidity. With Hammond's scale, which is graded a shade wider, meat brightened from 1·5 to 3·5 grades, depending upon the animal and upon conditions. A rapid drying of the meat surface seems to prohibit maximum brightening, although it does not appear to influence the rate of brightening to any appreciable extent. At ordinary room temperatures and humidity (approximately 18-20° C. and 55-60 per cent. relative humidity) it would seem that constant colour readings may be obtained after the first 30 minutes and up to about 4 hours after cutting. At storage temperatures above freezing and the same relative humidity, it is safer not to take readings before the elapse of 5 hours after cutting. The above suggestions are based upon relatively few tests and should be considered only as tentative. Where meat colour results are to be compared between experiments done at different times, it is desirable that samples should be read always at the same time after cutting and under similar conditions of temperature and humidity, and that sufficient time be allowed to permit those normal samples which brighten most, to reach their maximum brightness before reading, for it is this type of meat which is of greatest value to the trade.

Darkness of meat may be divided into two classes. It may be a matter of the intensity of red colour produced by a relatively high content of muscle haemoglobin, or it may be caused by incomplete oxygenation of muscle haemoglobin, in which case the tissue may be so impermeable to atmospheric gases that the brightening process takes place very slowly or not at all. The Kansas Experiment Station* treated rib cuts of two typical "black cutters" whose meat was a chocolate brown colour, by finely mincing the meat, placing it in a vacuum desiccator which had been evacuated to a high vacuum, and then allowing the desiccator to fill with oxygen. Within a few minutes the meat had turned a bright normal red colour. They found that these samples were extremely colloidal and extremely hydrophylic, and suggest that the mineral balance may have much to do with the unusual physical properties of the meat. No feeding experiments have succeeded in producing dark cutters, and no attempts have as yet been made to find whether genetics plays any part in the phenomenon.

Another type of discolouration frequently encountered over longer periods of storage, is the changing of the normal red colour of meat, to a brown hue, due to the oxidation of haemoglobin to a ferri-compound known as methaemoglobin. This process does not occur in the absence of oxygen, but proceeds most rapidly at 0° C. with an oxygen pressure of 4 mm., which increases with rising temperature (Brooks, 1929). For this reason, if a sample of stored beef be examined it will frequently be found that there is a dark brown layer, not at the actual surface, but one or two millimetres

* Permission was obtained from the Kansas Agric. Experimental Station, U.S.A., to quote experiments published in a confidential Progress Report on their meat investigations (July, 1932).

from the surface. Similarly, in high concentration of carbon di-oxide, the partial pressure of oxygen is reduced and therefore discolouration is nearer the surface and is more noticeable (Brooks, 1933). Methaemoglobin is formed in the frozen state, but is less, the lower the temperature. Thus Brooks (1933) finds that, whereas there is a significant discolouration after 8 weeks at -5° C., there is none after 15 weeks at -20° C. On the other hand the oxygen penetration of muscle at 0° C. is approximately 2 mm., while at 15° C. it is 1 mm. (Brooks, 1929), so that the higher the temperature above freezing the shallower will be the depth of methaemoglobin formation, although forming more rapidly at the higher temperature. Where humidity is low however, methaemoglobin formation will be wholly or partially masked by the deepening of colour due to surface drying of the meat. In meat which has been frozen and thawed the rate of pigment oxidation is increased, and frozen meat therefore suffers from the handicap that its colour is not so bright as that of unfrozen meat. The concentration of colour by drying of the meat surface is favourable to some extent as it masks the methaemoglobin formation, but in frozen beef where drying decreases the intensity of colour, this does not occur. Bacteria may increase methaemoglobin formation (Brooks, 1933; Heiss *et al*, 1933). In transport thus, chilling temperatures, considered in conjunction with other changes which beef undergoes in storage, may be considered optimal for retention of quality.

One other factor which strongly affects the sales value of a carcase is the freshness of appearance in which it is presented on the market, commonly known as " bloom ". The use of the term applies chiefly to the external appearance of the carcase which is most affected by the vicissitudes of storage; loss of bloom is most important in frozen meat and particularly in lamb and mutton.

The thin, broad, red surface muscle (*panniculus carnosus*) stretching over a considerable area of the ribs and flank of the carcase, and certain flexor muscles of the leg, are chiefly involved. The *panniculus carnosus* is covered by a layer of connective tissue and often by a thin layer of fat. Griffiths, Vickery and Holmes (1932) have fully surveyed the causes of loss of bloom. The effect on the colour of a muscle when it dries has been previously pointed out; on a thin muscle like the *panniculus carnosus* the effect, rather than darkening the colour, is to intensify it. Conditions leading to further drying however, and extreme desiccation of the muscle, cause the formation of minute air-pockets among the desiccated fibres, so that the scattering of light from the numerous interfaces thus formed decreases the depth of the reflecting layer, and the muscle appears to have lost depth of colour resulting in the greyish-yellow colour described as " corkiness ". At the same time a penetration of oxygen, which is not prevented by the connective tissue layer, causes the formation of methaemoglobin, and Brooks (1929) states that in practice, discolouration is usually a product of both these factors.

Thicker muscles lose brightness of colour on freezing through the presence of ice crystals and concentration of salts in the unfrozen portion.

Alterations in the structure of the connective tissue affect bloom. Prolonged contact with water which may take place during swabbing, during dressing, or through sweating (caused by temperature fluctuations) increases the capacity by swelling the collagen fibres, and causes an apparent dullness of the underlying fat and muscle (Moran et al., 1929). Again, freezing the tissues disrupts the swollen collagen fibres and increases opacity. When the tissue is not allowed to dry after freezing and/or thawing, a still greater opacity results. If normal appearance of the superficial tissues is to be retained, conditions leading to swelling or excessive drying of the frozen connective tissue must be avoided. For lamb and mutton about 10 hours on the cooling floor at 12° C. and relative humidity as near saturation point as possible, is recommended (Griffiths et al., 1932). However, from the point of view of "bloom", good results are also obtained by placing warm carcases direct into the freezer. In freezing, temperatures should be maintained just below −8° C. and relative humidity at approximately 75 per cent., a combination which, while reducing spoilage by micro-organisms to a minimum will maintain the optimum appearance of carcases.

In the fat, gross chemical changes in saturated or unsaturated fatty acids, a change to colourless or leuco-compounds giving the appearance of bleaching, or crystallisation of super-cooled or rapidly cooled fats, may influence the opacity of fat and consequently bloom (Moran et al., 1928), but these factors are relatively unimportant, and the crystallisation which most frequently occurs has no significant effect on the bloom of a carcase (Griffiths et al., 1932).

These colour changes in the carcase occurring in storage have been treated at some length because they are important, and while none of them affect the edibility of meat, they have a profound influence on the attractiveness and hence sales value of carcases.

IV.—Factors Influencing the Colour of Fat.

The yellow colour of fat is due to the carotinoid pigments, carotin and xanthophyll. Fat from cattle and horses contains chiefly carotin, yellow fat from rabbits and poultry chiefly xanthophyll; the almost white fat of sheep and goats contains a meagre amount of carotin, and pig fat is altogether unpigmented (Neidig et al., 1928).

Breed.

Breed exerts a stronger influence on fat colour than any other factor. The colour of body-fat is closely allied to the colour of butterfat (Neidig et al., 1928); Hammond and Whetham have illustrated the marked breed differences in the butterfat colour of dairy cattle. Hammond (1935) considers the colour of the body-fat in cattle to be a multiple-factor genetic character, and states that all shades of colour exist from a very pale yellow (which is desired by the butcher) to a deep yellow (which is desired by the breeder of dairy cattle). The very yellow fat in the carcases of Jerseys and Guernseys is well known, and public discrimination against yellow fat is largely due to the association of yellow fat with the poor quality of meat common in dairy breeds. Holstein fat is not normally yellow, but it was found to have a bluish exterior colour compared with clear creamy-white fat of the Aberdeen Angus (Wisconsin Agric. Expt. Stn. Rept., 1927-28).

Condition.

The effect of condition on the colour of fat will be very largely dependent upon the amount of pigments the animal has ingested in the course of fattening, and whether during that time there was any fall in condition.

It was observed that in rabbits, which for various reasons (illness and starvation due to deformed teeth) had dropped greatly in weight, the fat colour had increased in depth far above normal. It seemed that while the body absorbed the fat for maintenance, the yellow pigment was not drawn out, and concentrated in the tissue, gave the abnormally dark colour. To test out this theory seven rabbits with potentially yellow fat were fattened (inbred line selected for yellow fat), a fat sample removed from one half of the shoulder strap for colour reading, the animal reduced to desired weight by starvation, killed, and the fat colour reading taken from the remaining half of the shoulder strap. The following represents the colour changes which occurred.

Rabbit No.	Starved Weight at Operation.	Weight when Killed.	Loss in Weight.	Operation Sample.	Killing Sample.	Condition when Killed.
	Gms.	Gms.	Per cent.	Colour.	Colour.	
1...........	2,731	1,890	31	6	11	Very Lean.
2...........	3,225	2,930	11	4	5	Good.
3...........	3,275	2,560	22	7	7·5	Very Good.
4...........	3,540	2,820	20	8	9	Good.
5...........	3,437	3,090	10	8·5	9	Fair.
6...........	3,422	2,637	23	7·5	9	Fair.
7...........	3,080	2,480	19	8	13	Very Lean.

(The higher the grade, the yellower the fat).

The most striking concentration of colour was shown in rabbits Nos. 1 and 7, which were very lean when killed. Nos. 2, 3 and 4 which were still in good condition when killed had become but little yellower. No. 2 which had a very light coloured fat, while losing only about half the weight that 3 and 4 lost, deepened in colour to the same extent. On the other hand No. 5 which was in the same condition as No. 6 when killed, but had lost in weight only about half as much as No. 6, showed a correspondingly smaller increase in colour. Samples of Nos. 5 and 6 were rendered, this method giving more homogeneous samples for comparison; although it was found impossible to match rendered samples on the scale, direct comparisons between samples were possible. Contrasts in the rendered fats correspond to those taken by scale on the fresh fat.

We do not wish to attach much value to the preciseness of the differences between Nos. 2, 3, 4, 5, and 6, but at the same time find some indication of deepened colour in every case. An exact method for determining the concentration of pigment would be by quantitative chemical analysis. Further fat colour readings taken on each of seven lean rabbits which had once been in good condition, averaged 11·3; readings on ten rabbits in good condition averaged 8·6, a striking difference.

If the carotin in beef fat concentrates in the same manner as xanthophyll in rabbit fat when fat is absorbed by the body, a partial explanation is offered for the rather yellow fat of range-grazed three-year-old animals when not in first-rate condition. Fat added when grazing is good, is lost in the store period during the sparse season; a sequence of this nature would tend yearly to increase the amount of pigment in the adipose tissue. Livesay (1929) found the fat of higher grade steers, i.e. fatter steers, to have a more desirable colour. The reason is probably found in the dilution of the pigment on fattening on rations largely devoid of carotinoids (see Feeding).

Age.

A litter of five rabbits from a yellow-fat strain (colour 8·6) were divided after weaning into groups of 3 and 2 and fed differently to test the influence of feed on the colour of the fat. In the green fed lot, No. 1 died 2 weeks after weaning; the little fat present was colourless. No. 2 which was sick and so killed at 9 weeks after weaning, had a fat colour of 1·5. No. 3 grew normally, was killed at 33 weeks old, and had a fat colour of 4. In the white feed lot. No. 4 killed at 13 weeks after weaning had fat colour 1·5, while No. 5 which died at 38 weeks old, having dropped in weight from 2,445 gms to 1,740 gms in 6 weeks, had a colour of 3. Davis (1932) states that the fat of yearling beef animals is somewhat whiter than that of mature animals. Age seems to have an influence in increasing the yellow pigment in the fat, probably because of the increase in total amount of the pigment ingested with age.

Sex.

Bull *et al* (1930) find no difference in the colour of fat between steers and heifers. Rabbit data shows no difference between bucks and does.

Feeding.

Perhaps the most important factor influencing the colour of fat in practice, is feeding. It is well known that when animals are out to green grass (rich in carotinoids), the colour of both the body-fat and butterfat increases in intensity. Palmer (1922) has demonstrated conclusively that the carotin content of the cow's adipose tissue as well as that secreted in the milk fat, is determined by the carotin content of the ration. In a similar way the fat colour of the fowl and the yolk of the egg, is dependent upon the xanthophyll provided in the feed. Watson (1933) obtained a striking increase in colour of butterfat when stalled dairy cattle were allowed out to grass.

Pease (1928) has shown that if the yellow-fat strains of rabbits are fed on foods such as yellow maize and green foods, yellow fat is always deposited, but if pigment-free foods are fed the fat deposited is white. Similarly we found (see p. 451, Age) that a rabbit 33 weeks old and fed on carotinoid-rich food had a fat colour of 4, while one fed on food deficient in pigment, at 38 weeks old, in spite of a considerable loss of fat (which tends to concentrate colour), had a grade of only 3.

In practical experiments (Kansas Agr. Expt. Stn. Rept., 1930-32) it was found that animals on a full concentrate ration plus blue grass pasture [rich in carotinoids (Neidig et al., 1919)] for 150 days, contained more yellow units in their fat than animals getting no green grass. This period was however insufficient to discolour the fat, giving it only a pinkish appearance often described as " muddy " by packer-beef men. The calves used were reared in Texas and it is reasonable to suppose that their main feed prior to fattening had been grass. The beef breeds have a natural tendency to white fat and fat added in a fattening period on a main ration low in carotin, evidently served to dilute any pigment which may have been laid down on grass to an extent sufficient to produce a desirable article. This fact has an important bearing on cattle fattened off the range and shows that, provided animals are young enough so that not too much pigment has been laid down, range reared cattle may produce fat of a desirable colour.

Storage.

Lee (1931a) has shown how fat bleaches by oxidation. We observed changes in the colour of rabbit fat under different conditions over a period of five months. In short, storage of shoulder and kidney fat in the dark for 3 months at 0° C. left the normal colour of 9 unaltered, except for the kidney fat which appeared to reach grade 11 on thawing. After keeping for 2 months in light at 18° C., it had bleached to 8. Fat stored at − 10° C. appeared to have bleached from 9 to 5, but on thawing regained normal colour. Crystallisation of the fat may account for this illusion when frozen. The shoulder fat (0° C. and −10° C. samples) when kept in light for 2 months at 18° C. subsequent to thawing, bleached from 9 to 4. The kidney fat stored at −10° C. for 3 months had not bleached at the end of another month in light at 18° C., so was refrozen at −20° C. for three days, dropped from 9 to 4 in storage, darkened on thawing from 4 to 10, and in 5 weeks the surface had bleached to 2. An eighth of an inch down the colour was still normal, namely 9.

How rapidly this bleaching occurs in beef fat we do not know. Mattikow (1932) states that in solution, carotin (beef) bleaches more rapidly than xanthophyll (rabbits). In rabbit fat it was noticed that the drier the sample, the more rapidly bleaching occurred, due probably to the better penetration of oxygen where an oily surface layer was absent. It is alleged that bleaching of beef fat is accelerated by " shrouding ", i.e. pinning hot damp cloths tightly over the carcase after killing. (Readings in Packing House Practice, 1934.)

The reason for a disfiguring brown discolouration of fat travelling long distances, as from Australia for example, has been explained by Brooks and Lea (1933a). In bleeding, beef fat retains an appreciable amount of blood haemoglobin in the capillaries, which imparts to the fat a pinkish tinge, and which on changing to methaemoglobin gives the fat a brown, or a dead, chalky appearance, according to the amount of haemoglobin originally present. These discoloured patches are most frequent where carcases have chafed in transport, so keeping the fat surface moist, a condition conducive to methaemoglobin formation. (The practice in South America of running cattle through a cold shower-bath before slaughtering, by contracting the skin, probably has a beneficial effect on clearing blood from the surface-fat capillaries.) In experiments, the discolouration occurred already in 3-5 days at 0° C. in an atmosphere of 95 per cent. carbon dioxide and 95 per cent. relative humidity; in 50 per cent. carbon dioxide it occurred in about 30 days and in 10 per cent. carbon dioxide or in air, only after about 60 days (Brooks and Lea, 1933b).

Brooks and Lea (1933a) state further that the optical properties of the connective tissue and the fat determine the depth to which light penetrates before reflection, the more transparent the material the deeper being the colour. They consider that the composition of the adipose tissue in terms of fat, protein and water affects this transparency.

V.—Factors Influencing the Firmness of Fat.

In meat animals the firmest fat is found in sheep, followed by cattle, and the softest in pigs, and it is only in the latter that soft fat is a serious problem. Henriques and Hansen (1899-1900), feeding linseed oil and cocoanut oil to pigs, did the classical experiment showing how the nature of the food influenced the firmness of fat. This was the commencement of a great deal of research on the soft fat problem in pigs, and Callow (1935) has comprehensively reviewed what is known about it. In beef, maize, soybeans, maize oil and soybean oil (all softening pork fat) were unable to influence the firmness of beef fat (1933); the extremes, cocoanut oil (iodine number 8·1) and Menhaden oil (iodine number 139·2 to 192·9) gave no significant difference in firmness of fat (unpublished data of the Iowa Agricultural Experiment Station), but the experiment is not conclusive. Hammond (1932) states that grass-fed animals produce soft fat, and quotes as a possible reason Sjollema's (1903) finding that the feeding substances which ferment much in the rumen cause the formation of volatile fatty acids (which softened butterfat). Hammond states further that the over-hard fat of animals fattened on roots (a carbohydrate feed) may be softened by linseed cake (containing oil), while the soft fat of animals off grass may be firmed up with cotton cake or carbohydrates.

The effect of age on the firmness of fat has not been sharply dissociated from the possible effect of condition. The fat of calves fed at Illinois (Ann. Rept., 1927-28) was hard at the beginning of a trial; after 140 days it had softened appreciably, but after a further 60 days had hardened to the firmness of the original reading; another 60 days of feeding produced no change in refractive index. At Kansas (Ann. Rept., 1928-30) on the other hand it was found that the fatter the animal the softer the fat, which agrees with the Illinois results up to the 140 day feeding period. Leighton and Douglas (1910) state that the fat of old cows is softer than that of young animals; Langer (1919) found that the fat of full-grown cattle contained more oleic and less stearic acid than the newborn. As animals are, however, sold fairly young in commercial beef production, age is not likely to play an important part in softening fat.

Regarding the effect of condition, it is claimed that fattening served to decrease the firmness of beef fat (Ill. Ann. Rept., 1927-28). That will probably depend chiefly on the nature of the fattening ration, but just how much feed may influence firmness in beef fat is unknown. Exercise has no effect on firmness (Ill. Ann. Rept., 1929-30); steer and heifer beef show no differences (Ill. Ann. Rept., 1927-28; Bull et al., 1930).

VI.—Factors Influencing the Amount of Intramuscular Fat (Marbling) in the Meat.

Marbling is of very great importance in beef, for the interspersion of fat between muscle bundles and fibres gives beef a tenderness, juiciness and flavour that is lacking without marbling. Hammond (1932) states that greater tenderness is probably due to the breaking up of the connective tissue by the fat deposited in it. He and Wood and Newman (1928) have described the distribution of marbling fat and show that in well finished carcases the later maturing parts such as the loin and ribs (the most expensive cuts) are best marbled.

Breed.

Hammond (1932) finds a great difference in marbling between domesticated and undomesticated breeds of sheep. Considerable differences within a breed are indicated by figures of 2·1 and 1·0 for Suffolks of equal age and fatness. The marbling in different breeds of sheep is shown in Table XVII. In cattle Adametz (1888) found that the unimproved Steppe cattle had much less fat in the muscle than did the Dutch and Shorthorn cattle. The Aberdeen Angus, Galloway, Red Poll, Devon and Aberdeen Angus × Shorthorn show no significant breed differences (see Table XVIII).

Condition.

Edinger (1925) finds that the thicker the external fat, the better is the marbling. Our results with sheep show the same. Robertson and Baker (1933) found true fats in abundance in the connective tissue of the muscles of full-fed cattle, while only traces were found in a rough-fed steer. The findings of Hankins and Burk (1932) who worked with 2,073 individuals, are conclusive. The correlation between thickness of external fat and marbling was $+\cdot 88 \pm \cdot 003$; thickness of flesh (good development), and uniformity of width of carcase, were also rather highly correlated with marbling.

Age.

Most authorities agree that marbling increases with age (Hammond, 1932; Helser, 1930; Foster, 1928), but few have dissociated the effect of age and the natural fattening accompanying age. Bull *et al* (Ill. An. Rept., 1931-32) found no difference in marbling between calves (baby beef) and yearlings, where the calves had 31 per cent. fat in the carcase and the yearlings 35·2 per cent., which means that neither thickness of fat nor age increased the marbling in this case. In sheep we find a small age difference independent of fatness. In cattle the marbling of the Angus definitely increased with an age increase from 15 months to 22 months (see Table XX), but the increase is connected with a great increase in fatness. From 22 to 33 months where little fat is added, marbling improved but little. An age increase from 22 to 33 months in the Galloway heifers on the other hand, in spite of a non-significant fat increase, produced a significant difference in marbling, while steers had a marbling percentage increase considerably greater than the fat percentage increase. A breed difference is indicated and a chemical analysis of the amount of connective tissue (the depository for marbling fat) in the muscle of the Angus and Galloway, might offer some explanation of this discrepancy; furthermore, the Angus, an earlier maturing breed than the Galloway, has at 22 months probably attained the maximum development of marbling in proportion to the thickness of subcutaneous fat, which the Galloway perhaps has not.

Sex.

Hammond (1932) finds only a small difference in marbling between rams and ewes and states that the marbling seemed to depend largely upon the state of fatness of the animal and the strain, these differences being larger than differences between the sexes. The marbling of rams was coarser than in wethers. Leighton and Douglas (1910) and Hall (1910) agree that bulls are poorly marbled; Hammond explains the difference on grounds of sex activity. Heifer beef is supposed by some to be better marbled than steer beef (Helser, 1932; Trowbridge *et al.*, 1931), but others found that sex made no difference in spite of heifers being the fatter (Trowbridge *et al.*, 1932; Ill. An. Rept., 1927-28). Foster and Miller (1933) found heifers, although not a great deal fatter than steers, to have more fat in the eye-muscle, which points to better marbling. Our figures show no significant sex differences in cattle (see Table XXI). There is no reason to believe that there is any difference in marbling in steer and heifer carcases of equal fatness, and where heifers do have better marbling it is probably due to a thicker finish.

Exercise.

No other factors are known to affect marbling except perhaps the temperament and management of the animals, i.e. with a low metabolism of the muscle, fat will be more readily deposited in it. Hammond (1932) states that if the animal is kept quiet, more fat will be deposited in the muscle, but if it is leading an active life little fat will go into the muscle itself, although it may be deposited in other parts not so much affected by exercise as the muscles.

VII.—Factors Influencing the Flavour of the Meat and Fat.

Flavour in meat is still an elusive factor of which little is known. Hammond (1932) states that the extractives influencing flavour are possibly ethereal salts of aromatic ring compounds which in small quantities give meat a pleasant flavour, but in large quantities become disagreeable. Hall and Emmett (1912) state that the organic extractives (water soluble) aid in giving meat its flavour; the more important, the nitrogenous extractives, consist largely of creatin and purin. Mitchell and Hamilton (Ill. An. Rept., 1927-28) think that the flavouring substances of meat are probably largely, if not entirely, water soluble, and while they probably contain nitrogen, they cannot be proteins, since the proteins of meat are tasteless; further, that differences in flavour are dependent more upon differences in occurrence of individual extractives than on the total extractive material present.

Breed.

Each species of animal has its own characteristic flavour and odour of meat; goat flesh for example is particularly strong compared with mutton. Sheets (1934) states that in co-operative meat experiments in U.S.A. no differences in flavour have been detected between breeds of a species.

Condition.

Foster and Miller (1933) find roasts slightly more palatable the fatter the animal. Sheets (1934) states that thinly fleshed lambs and cattle give the poorest flavoured meat. Armsby (1917) mentions that with fattening there is a gain in the soluble nitrogenous extractives of muscle, which points to an increase in flavour.

Good flavour is commonly associated with good marbling (prime conditions) and on the basis of Armsby's findings is explained by the increase of soluble extractives of muscle with fattening, for fat in itself is relatively flavourless except where browning has caused a high flavour by formation of sebacic acid. Hammond (1932) on the other hand found no connection between marbling and flavour between muscles in the same animal, and states that while marbling fat undoubtedly influences the eating qualities of meat, it does so more by the effect it has on smoothness of eating than on the flavour. While this is undoubtedly true, it is likely that in the most used muslces the relative marbling is less, and the flavour highest because of the darker colour, and although Hammond's correlation is not negative, the very weak positive correlation may be caused by this factor. In short, marbling, while not directly influencing flavour, may be associated with it by a coincident increase of marbling and soluble nitrogenous muscle extractives with rising condition.

Age.

It is agreed that flavour increases with age (Hammond, 1932; Leighton *et al.*, 1910). Roasts from mature carcases scored higher in aroma, colour, flavour and juiciness than roasts from immature carcases ,Foster, 1928; Iowa An. Rept., 1929). Hammond (1932) found a correlation between high flavour and dark colour in muscle, and Lehmann (1904) a higher extractive content in red muscles than in white muscles, stating that the former have the most pronounced flavour. In the same way veal is relatively tasteless compared with mature beef.

Sex.

Authorities agree that the meat of the uncastrated male is stronger and less pleasant in flavour than meat from steers or wethers (Hammond, 1932; Leighton *et al.*, 1910), and that generally there is no difference in flavour between steer and heifer beef (Foster *et al.*, 1933; Trowbridge *et al.*, 1932; Hankins, 1932; Helser *et al.*, 1932; Ill. An. Rept., 1927-28).

Feeding.

In pigs it is known that a fishy taste may be imparted to the meat if more than 5 per cent. of fishmeal is fed in the ration up to the time of killing. Tainting is believed to be largely due to rancidity of the fish oil rather than the amount fed, although with an *ad lib.* supply of fresh fish tainting is observed (De Lisle, 1930). In cattle, Sheets (1934) states that the nature of the feed has no influence on the flavour of the meat. On the other hand, mutton grazed on the aromatic bush of the South African Karroo, seems to have a better flavour than meat raised in the grass areas.

Storage.

The efficiency of storage may influence the flavour of meat to a considerable extent, not so much by improving the flavour of fresh meat, but by preventing bad flavours introduced by breakdown products resulting from attack by micro-organisms. Moran and Smith (1929) find no improvement in the flavour of meat after ripening or storage, and state that as no chemical changes occur in the meat, flavour is not altered. Hall and Emmett (1912) on the other hand claim that flavour is improved during ripening to some extent by an increase in organic extractives. Up to 30 days hanging autolysis or breakdown of the proteins by intrinsic ferments, does not occur (Moran *et al.*, 1929), but meat stored for 180 days gradually underwent a change in flavour by this reaction, which resulted in a stale flavour rather than improvement (Hoagland *et al.*, 1917). But perhaps the most important factor enhancing flavour during ripening is the attack of putrefactive micro-organisms in its incipient stages. The flavour increases progressively, until meat becomes "high", after which it is inedible. Temperature probably has a considerable influence on development of this type of flavour, as bacteria will flourish best at higher temperatures. In commercial refrigerators however, where a relatively low temperature is necessary to prevent drying out of the carcase, it seems that meat will have but little chance to improve in flavour. In tests by Lampitt and Moran (1933) rapidly frozen meat had a somewhat better flavour on cooking than similar cuts slowly frozen.

Storage does nothing to improve flavour of fat, but is extremely important in preventing rancidification, the slightest suspicion of which is universally unpopular. Rancidification occurs as a result of the action of enzymes, moulds and bacteria, and by oxidation with atmospheric oxygen. The general effect is a breakdown of the fat molecule with the formation of fatty acids, while simultaneously an oxidative change takes place, encouraged by the free acidity, which results in the formation of substances of disagreeable flavour and odour (Moran *et al.*, 1929). Lee (1931) has shown that oxidation and acidification of mutton fat held for 7 months at $-5°$ C. and 3 days at $12°$ C., was very slight and not sufficient to affect palatability, provided it was not exposed to strong light, which hastens oxidation. Mould growth was prevented at $-10°$ C. and growth at $-5°$ C. was insufficient to influence flavour deleteriously. Drying off of the fat surface of beef assists its keeping qualities (Lea, 1931). Over a period of about 40 days at $-1{\cdot}6°$ C. followed by 4 days hanging at $10°$ C., no rancidification occurs provided the fat is not unduly exposed to strong light. Moran, (1934) finds that frozen mutton and beef may be kept sweet for 18 months.

In rancidification two flavours are distinguishable, firstly a tallowy flavour caused by oxidation, and secondly and more important, a bitter or cheesy taint which is most frequently found in the region of the brisket fat. Blood drains to these parts and is readily attacked by micro-organisms which produce strongly flavoured products, small quantities of which are sufficient to send the fat " off ". Free acidity in itself is unimportant in influencing flavour and is considered rather as an index to the activity of micro-organisms (Lea, 1931). Whilst ultimate rancidification is inevitable with prolonged storage, its onset can be delayed by storing the fat at low temperatures by which means the rate of enzyme and chemical action is diminished. Careful handling and clean storage minimise attack by micro-organisms, while feeding for a firm fat reduces the rate of oxidation and postpones rancidity.

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