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Anatomical Studies of the Composition of the Pig Carcass at Different Stages of Growth

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Introduction

Hammond (1932) studied the form and composition of sheep at various stages of growth. He showed that bone, muscle and fat have different rates of growth and in consequence a different order of development, and that within each of these tissues there is differential growth. Subsequently, McMeekan (1940-41) working with pigs confirmed Hammond's findings on sheep by showing the existence of differential growth between and within the tissues bone, muscle and fat. He observed the effect which various levels of nutrition have on the form and composition of the pig. He showed that in pigs fed on a low plane of nutrition bone develops relatively more than the muscle or fat. On the other hand, in pigs fed on a high plane of nutrition, muscle and fat develop more than bone. However, Wallace (1948) re-examined McMeekan's data and found little evidence that growth of muscle and bone was differentially affected by nutrition, for the muscle/bone ratio in the pigs on his various treatments appeared to be much as might be expected if the differences in skeletal (or total muscle) weight were taken into consideration. Wallace also disagreed with the view put forward by McMeekan that between the anatomical units of each tissue some parts are penalised proportionally more than others when the growing animal is under-nourished. He believes that if McMeekan had compared the weights of parts of the skeleton, for instance, at equal skeletal and not at equal body weights he would have found the skeletal pro-

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caution. In general they should only be used in circumstances similar to those in which they were formulated. Snell (1892) formulated an equation to relate the growth of brain weight with body weight. The simplest mathematical expression of this is $E = kS^r$, in which E is the weight of the differentially growing brain, S is the weight of the body, r the exponent of relative morphological development and k, which is of no particular biological significance, denotes the value of E when S equals unity. Huxley (1932) as a result of his experiments suggested that this formula could be widely applied to relate the growth of any part of an organism to the total growth of the organism as expressed, say, in its total weight or length. This equation has been criticised on the grounds that body form and composition are not governed solely by the total size attained, which the equation implies, but also by the rate at which growth occurs. It is clear that constants derived from this allometric equation must be considered in relation to the level of nutrition prevailing when they are obtained.

Object of the Experiment

Hammond (1932) in studying the growth of sheep used a dissection technique which was later used for pigs by McMeekan (1940-41). McMeekan's technique was to divide the carcass into nine anatomical joints. These were head, neck, thorax, loin, pelvis, two legs and two shoulders. Each joint was then broken down into its main components, skin, subcutaneous fat, intermuscular fat, muscle, brain and spinal cord, tendon, glandular tissue and waste. Muscles were weighed in bulk for each joint and no attempt was made to dissect out and weigh each muscle. Since McMeekan's dissections other workers on pigs have used this technique or minor modifications of it. The technique has been of great value in establishing some general principles of growth and the effect which various nutritional regimes have on it, but it is open to criticism as being neither a strictly anatomical nor a strictly commercial technique. For example, some muscles, notably the longissimus dorsi, appear in at least three different regions.

The object of the present experiment was to make a more detailed study of growth at the fundamental anatomical level since it was felt that this was required for a fuller understanding of the structural changes occurring during growth. Furthermore, attempts to evaluate carcasses on a basis of sample measurements and commercial cuts have yielded results which are difficult to interpret biologically (Bodwell, Harrington, Pomeroy & Williams, 1959) and it was anticipated that anatomical studies would provide a basis for the interpretation of results obtained by these methods.

Experimental Material and Methods

MATERIAL

The experimental material was obtained from a larger experiment organised by the National Pig Progeny Testing Board which was designed to investigate the possibilities of using a commercial type of dissection in the evaluation of the pork, bacon and manufacturing carcass.

Each of 10 pedigree Large White boars was mated to 4 pedigree Large White Sows which were not full sisters to produce 4 litters per boar. From each litter 3 hogs and 3 gilts were selected. One of each sex was allocated at random to one of 3 treatments. The treatments were rearing to pork weight, 150 lb., to bacon weight, 200 lb., and to manufacturing weight, 260 lb..

The pigs started on the experiment at 50 lb. liveweight and were reared under the standard conditions of management pertaining at a pig progeny testing station. The pigs were fed to appetite twice daily on the same ration and weighed weekly. At 130 lb. liveweight they were gradually changed on to a lower protein ration which they continued to be fed until slaughter. The ration change was considered to have little effect on the pork pigs. The composition of the rations is given in Appendix 2.

The sample for anatomical dissection was obtained by selecting 5 out of the 10 boars, and from the progeny of each of these 5 boars 2 litters were taken at random. From each of these litters the right side of the 3

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hogs was used for dissection.

METHODS a) Slaughter-house procedure

The experimental pigs were slaughtered on the day of their weekly weighing when they weighed not less than the final live-weight of the treatment. Just before leaving the testing station for the slaughter-house the pigs were weighed, and this weight was taken as the last live-weight.

On arrival at the slaughter-house the pigs went through the normal process of stunning, bleeding and removal of viscera. At this stage all the experimental carcasses were divided into two sides. This process was always carried out by the same person and involved chopping out the centre of the vertebral column from the tail to the atlas. The portion of the vertebral column removed, commercially called the chine bone, was retained for subsequent treatment at the laboratory. The head was then removed from the carcass and weighed and the two sides were thus formed. The sides were weighed and a number of other measurements were taken. The side was then stored overnight in a chill-room at approximately 38°F.. On the following day a number of subjective assessments were made. The side with its chine bone was then quickly despatched to the laboratory.

From the records kept for each pig during its lifetime it was possible to know its age at slaughter, its daily gain in weight during the experimental growing period, its food conversion ratio and its carcass dressing percentage.

b) Dissection Procedure

On arrival at the laboratory the medial, lateral and dorsal faces of the side were photographed beside a metre rule. The side was then weighed on a steelyard to the nearest ounce and its vertebral formula determined.

Each side was completely dissected before another side was started. Until such time as it could be dissected it was stored in a polythene bag at - 1°C.. The period of storage varied from 0 - 12 days according to

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the number of experimental sides arriving for dissection at any one time and to the man-power available.

Immediately before each dissection the side was re-weighed to the nearest ounce. In general the weight loss during storage was only a few ounces. The side was then laid on the dissection table with its medial face upwards and was completely wrapped in cold damp cloths to minimise loss of moisture. Throughout the dissection it was kept covered by damp cloths and any handling of fat, muscle or bone with the fingers was avoided by working through the towel itself or with forceps. Each evening, the portion of a side remaining after a day's dissection was wrapped in damp cloths, placed in a polythene bag and stored overnight at -1°C.. For the actual dissection a surgical scalpel with detachable blades was used. All parts dissected from the side were weighed on a balance to the nearest 0.1 g..

The kidney was removed and weighed. The glands embedded in the flare and kidney fat were dissected out and the adherent fat was removed with scissors. The glands and the trimmed fat were weighed separately and the weight of the latter was added to the weight of the flare and kidney fat. The flare and kidney fat could not be separated accurately and these were weighed together as flare fat. A weighed sample of fat from around the kidney was kept for chemical analysis.

Next, the subcutaneous fat and skin were removed in regions as soon as it became necessary to remove the underlying muscles. The delineation of the three subcutaneous fat and skin regions, ham, middle and shoulder, roughly corresponded with commercial practice. The line dividing the ham from the middle was obtained by placing a large knife against the anterior edge of the symphysis pubis and at right angles to the dorsal skin. A superficial cut on the dorsal and ventral skin and subcutaneous fat was made with the knife in this position. A piece of string was tied round the carcass in such a way as to describe on the lateral face of the side the position of the superficial cuts just made. A superficial cut was made along the line formed by the string. The line dividing the middle from the shoulder subcutaneous fat and skin was obtained by placing the large knife at the base of the posterior edge of the 4th. thoracic vertebra and at right angles to the dorsal skin. A superficial cut was made on the dorsal and ventral skin and subcutaneous fat with the knife in this position. A piece of string was used again to describe on the lateral face of the side the position of the superficial cuts just made. A superficial cut was made along the line formed by the string.

The ham skin and subcutaneous fat were now removed together as far as possible and any of the latter still remaining was removed. The definition of subcutaneous fat was necessarily somewhat arbitrary in places, but where the distinction between the subcutaneous and the intermuscular fat was not obvious, the fat was classified as subcutaneous until it reached the same horizontal level as the two adjacent peripheral muscles as the side lay on the dissection table. The skin was then trimmed of adhering subcutaneous fat by using a sharp knife and the skin and subcutaneous fat were weighed separately. The part of the pre-crural glands lying in the subcutaneous fat was dissected out and weighed.

It was now possible to start removing the muscles, and these were identified and classified according to the nomenclature of Sisson and Grossman (1953). The medial thigh, tail and sublumbar muscles were the first to be removed along with adhering intermuscular fat and they were weighed individually in this state. The intermuscular fat was removed with a pair of scissors but only fat lying on the surface of the muscle was removed and weighed as such. Where a muscle was present in two or more of the commercial joints it was cut so that the part of the muscle belonging to each joint could be weighed. The procedure allowed the anatomical dissection to be related to the commercial dissection but this will not be dealt with in this paper. Intramuscular fat lying beneath the surface of the muscle was not removed. It was found that no easy separation could be made between intermuscular fat and connective tissue and they were weighed together as intermuscular fat. The intermuscular fat removed from each anatomical region was kept under a damp cloth until a suitable quantity had been obtained for weighing. The anatomical regions into which the intermuscular fat was divided will be found in Appendix 1. After the fat had been trimmed from each muscle it was weighed again. The purpose of weighing the muscle before and after trimming was to help to show any inaccuracies in weighing and also to give some idea of the loss during trimming in each major anatomical region. Tendon was included in the weight of trimmed muscle but it was also detached at its junction with the belly of the muscle and weighed separately. The procedure outlined for the above muscles after they had been dissected out applied to all the muscles of the side except the cutaneus. It was found that no accurate separation of psoas major and iliacus could be made and these were weighed together. However, for obtaining psoas major for chemical analysis a rough separation was made. Of the medial thigh muscles sartorius was kept for chemical analysis. The remainder of the hip and thigh muscles were now removed.

With quadriceps femoris only rectus femoris could be consistently dissected out with accuracy. The latter was retained for chemical analysis. Vastus intermedius, vastus medialis and vastus lateralis were weighed together. Before biceps femoris, tensor fascia lata and the gluteus muscles could be removed it was necessary to remove a small part of the middle skin and subcutaneous fat. The procedure adopted for the removal and subsequent treatment of the ham skin and subcutaneous fat was applied here. A sample of intermuscular fat for chemical analysis was taken from a deposit lying close to the femur on the medial face of the adductor.

The femur was now detached from the acetabulum and the muscles of the lower leg were dissected out. It was found that no accurate separation of gastrocnemius and soleus could be made, and that in view of the difficulties of separating the tendons of the gastrocnemius and the superficial digital flexor muscles they were weighed together as gastrocnemius. The belly of the superficial digital flexor was dissected out, weighed separately and retained for subsequent chemical analysis. The weight of tendon recorded for the deep digital flexor consisted of the tendons of tibialis posterior, flexor digitalis longus and flexor hallucis. The tendon of tibialis posterior was obtained by dissecting it out until it fused with the belly of flexor hallucis and the tendon of flexor ___

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digitalis longus by dissecting it out until it joined the tendon of flexor hallucis. Any tendon belonging to extensor digitalis brevis was classed as tendon of the long digital extensor. It was found that no accurate separation of the lateral digital extensor into its two parts could be made.

The bones of the hind-limb were now separated and weighed individually. Until they could be cleaned they were placed in a polythene bag which was wrapped in a damp cloth. Where the bones had to be kept for more than a few hours before cleaning they were stored at - 1° C.. Immediately before each bone was cleaned it was re-weighed to determine the storage loss. The bones were cleaned of all tendon and fat down to the bone surface. Most of the periosteum was removed in the process but care was t ken to leave all cartilage on the bone. Removed material was recorded for each bone as bone trimmings. In cleaning the tarsus, the bones were not separated and the fused 3rd. and 4th. metatarsals were cleaned as such. The rest of the bones of the foot were separated except that the phalanges belonging to the 2nd. and 5th. digits were cleaned as a whole. In the text, tables and figures the 1st., 2nd. and 3rd. phalanges refer to those of the 3rd. and 4th. digits. As in the hind foot, the bones of the fore-foot were separated into the corresponding parts and cleaned in a similar way to the hind-foot. The cleaning procedure just described was adopted for the rest of the bones of the side except that the anatomical sections of the vertebral column were cleaned as a whole and not as individual vertebrae. The chine bone which arrived at the laboratory at the same time as the side was usually cleaned on arrival. When it could not be cleaned immediately it was weighed, wrapped in a polythene bag and damp cloth and stored at - 1° C. until such time as it could be cleaned. The chine bone was first weighed and then divided into sections according to the vertebral formula already found after the spinal cord had been removed and weighed. The uncleaned tail was discarded after its weight had been subtracted from the total weight of the chine bone. Each of the vertebral sections was cleaned and weighed separately. The cleaned weight of each section was then divided by two to give the portion of the chine bone belonging to the side dissected. The section weights now obtained were added to the weights of the corresponding sections of the vertebral column of the side. After having been cleaned and weighed all bones were laid out to dry so as to obtain their dry weights.

The remainder of the middle skin and subcutaneous fat were next removed according to the procedure described for the ham subcutaneous fat and skin. The cutaneus was removed with the subcutaneous fat in which it is embedded and it was dissected out before the subcutaneous fat was removed from the skin. Subcutaneous fat adhering to the cutaneus was trimmed off and the former was added to the rest of the subcutaneous fat. The glands embedded in the subcutaneous fat were cleaned and weighed. A sample of subcutaneous fat was taken from the middle region for chemical analysis. It was obtained from a rectangular area (2" X 1") on the dorsal face running 2" posterior to the 1st. lumbar vertebra along the dorsal edge and 1" down the lateral face from the dorsal edge.

As many muscles as possible were dissected out without removing the shoulder skin and subcutaneous fat. Longissimus dorsi was divided into three parts; lumbar, thoracic and cervical. The separation between the thoracic and lumbar parts was made by cutting at right angles to the vertebral column between the last thoracic vertebra and the first lumbar vertebra. The division between the cervical and thoracic parts was made by cutting at right angles to the thoracic part of the vertebral column between the last cervical vertebra and the 1st. thoracic vertebra. The whole of the lumbar part of the longissimus dorsi was retained for chemical analysis, and a portion of the thoracic part about 1" wide taken at the 4 - 5th. thoracic vertebra was retained for the same purpose. The size of the spinalis et semi spinalis tended to be affected by errors in dividing the carcass into its sides. The intertransversales lumborum were included with the lumbar part of longissimus dorsi. Multifidus dorsi which included the interspinales, was divided into a lumbar and a thoracic part in the same way as longissimus dorsi. The weights obtained for multifidus

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dorsi were quite variable and some of this was due to errors in dividing the carcass into its two sides.

The shoulder skin and subcutaneous fat was removed and treated in the manner already outlined for the ham skin and subcutaneous fat. However, on the ventral side of the neck there is a large mass of glandular tissue and the subcutaneous fat adhering to it was classified as subcutaneous until it reached the same horizontal level as the adjacent peripheral muscles. The glands were then removed, trimmed of the adhering intermuscular fat and weighed. The intermuscular fat was then added to that obtained from the rest of the neck. The blood vessels were removed and treated in the same way as the glands. Partly embedded in the subcutaneous fat is the shoulder part of the cutaneus. This was dissected out; the subcutaneous fat was trimmed from it, added to the rest of the subcutaneous fat and the cutaneus then weighed.

The variability arising from the splitting of the carcass referred to above affected, to a certain extent, the size of some of the lateral cervical muscles. Some of the anterior cervical muscles around the atlas were also variable in size due to inaccuracies in the removal of the head at the atlas. In the shoulder girdle the only muscle which could be accurately separated into its two parts was the deep pectoral. In the fore-limb the separation between the infraspinatus and supraspinatus was somewhat arbitrary in places but they were separated in as similar a way as possible on each occasion. The lateral head of the triceps brachii was retained for chemical analysis. The tendon of the extensor of the 2nd. digit was very small and was classed as the tendon of the common digital extensor. It was found difficult to separate accurately the tendon of the superficial digital flexor from that of the deep digital flexor and the tendon of the former was included with that of the latter. The belly of the superficial digital flexor was dissected out and treated in the usual way. The deep digital flexor was weighed as a whole and then the belly of the humeral head was dissected out and weighed separately. The tendon of the deep digital flexor was obtained by adding together the

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tendons from the ulnar, radial and humeral heads. The belly of the humeral head of the deep digital flexor and the belly of extensor carpi radialis was retained for chemical analysis.

The time required for the complete dissection of one side was approximately 110 man-hours. The dissection time required for the manufacturing sides tended to be rather longer than that required for the pork and bacon sides. Over all the 30 sides the average loss in the dissection was 0.798% with a standard deviation of 0.258%. As might have been expected with a greater relative surface area the loss in the dissection of the pork sides was higher than that obtained in the bacon and manufacturing sides.

Results and Discussion

The pork, bacon and manufacture treatment groups reached the prescribed liveweights of 150, 200, and 260lb. at the average ages of 148.1, 176.1 and 212.5 days respectively. The percentage composit... at each age is shown in Table I below.

TABLE I

Bone, Muscle, Fat and Residue as Percentage of Side Weight

	148.1 days	176.1 days	212.5 days
Bone	10.37	9.45	8.28
Muscle	50.31	47.79	43.53
Fat	30.97	35.06	41.38
Residue	8.34	7.70	6.82

As would be expected there was a highly significant variation between the treatments pork, bacon and manufacture in each of the tissues bone, muscle and fat, but within each treatment group the variation between boars was not significant possibly due to a large between litters within boars variation. The results for all the boar groups on each treatment have, therefore, been pooled and averaged. The detailed analyses of the dissection data at each stage are incomplete but some of the data is given in Appendix 1 and some of the more interesting features of these data are considered here.

Figure 1 shows that between 148.1 and 212.5 days (i.e. 150 to 260lb. liveweight) tendon, bone, muscle and fat develop in that order. This is in agreement with the results obtained by McMeekan (1940-41) whose work appears to be the only one comparable in scope with the present study. However, in comparing the present results with those obtained by McMeekan three points must be borne in mind. Firstly, McMeekan's pigs did not go beyond about 220lb. liveweight, secondly, McMeekan was dealing with very small numbers of an inbred strain of Large White pig, and thirdly, the pattern of growth of the Large White pig may have been modified in some respects by selection during the period that has elapsed since McMeekan's work was carried out. It is necessary to make these provisos because references to McMeekan's results are made below.

I <u>Growth of Skeleton</u>

Of the anatomical groups of bones the sacrum was the latest developing at 176.1 days but at 212.5 days the cervical vertebrae were latest (Fig. 5). The latter showed fairly early development at 176.1 days but they grew rapidly after this suggesting a secondary wave of growth in this region. The growth of the cervical vertebrae up to 176.1 days is in agreement with McMeekan's results, but as stated above, the latter did not include any data for 212.5 days. The bones of the thorax and loin were later developing than the bones of the pelvic and thoracic limbs at both 176.1 and 212.5 days but they were earlier developing than the sacrum at 176.1 days and later developing than it at 212.5 days. The bones of the pelvic limb tended to be rather earlier developing than those of the thoracic limb at both ages.

Within the anatomical groups of bones there was further differential growth. The bones of the pelvic and thoracic limbs showed the same order of development and, therefore, only the pelvic limb need be considered in detail here (Fig. 6). At the distal end of the limb the 3rd. phalanges were the earliest developing bones at 176.1 and 212.5 days. Moving proximally the 2nd. phalanges were rather later developing followed by the 1st. phalanges. However, the apparent wave of growth ceased there since the metatarsals were earlier developing than the 1st. and 2nd. phalanges. There was another wave of growth moving up the limb from the metatarsals to the tibia and femur and then to the os coxa. The tibia appeared to be later developing than the femur but the difference was very slight. An examination of Palsson & Verges' (1952) data on sheep showed these two separate waves of growth in the limb, but McMeekan's (1940-41) data on the pig did not show this.

In the thorax and loin the thoracic vertebrae were markedly later developing than the lumbar vertebrae at both 176.1 and 212.5 days. At 176.1 days the sacrum was later developing than the thoracic vertebrae, but at 212.5 days both the lumbar and the thoracic vertebrae were later developing than the sacrum. The thoracic vertebrae were considerably later developing than the cervical vertebrae at both 176.1 and 212.5 days. These results at 176.1 days conflict with McMeekan's results on pigs of a similar age, i.e. that the lumbar vertebrae were later developing than the thoracic vertebrae.

The overall pattern of development of the bones from 148.1 to 212.5 days showed that waves of growth extended up the limbs from the metatarsals and metacarpals and posteriorly from the head towards the centre of the body with the sacrum fitting into the wave of growth between the os coxa and the lumbar vertebrae. The waves of growth appeared to extend rather more quickly forward from the pelvic limb to the centre of the body than the waves of growth which extended back from the head. The result has been that these waves of growth have converged further forward in the body than had previously been found by Hammond (1932) and Palsson and Verges (1952) with sheep, and by McMeekan (1940-41) with pigs.

II Growth of Muscle

The abdomen, thorax, back and loin muscles were the latest developing of the muscle groups at 176.1 and 212.5 days (Fig. 2). At 176.1 days the muscles of the tail and pelvic limb were somewhat earlier developing than the muscles of the thoracic limb but this position was reversed at 212.5 days. However, both these latter groups of muscles were earlier developing than those of the neck which in turn were earlier developing than the muscles of the abdomen, thorax, back and loin.

The muscles of the lower hind leg and foot were considerably earlier developing at 176.1 and 212.5 days than those of the tail, sublumbar, hip and thigh region. Within the latter group the sublumbar muscles were the latest developing but psoas minor was considerably earlier developing than the other muscles of the group. There were no outstanding differences in the development of the muscle groups within the hip and thigh region or between the lower hind leg and foot muscle groups.

Within the muscles of the thorax, abdomen, back and loin, the muscles of the back and loin were the latest developing at both 176.1 and 212.5 days and the muscles of the thorax were later developing than those of the abdomen at these two ages. Within the longissimus dorsi, the thoracic part and the spinalis et semispinalis, a muscle of the thoracic part of the side, were rather later developing than the lumbar part at 212.5 days (Fig. 4). Multifidus dorsi exhibited the opposite position but this may have been due to errors which arose when the carcass was split into its two sides.

The development of the muscles of the shoulder girdle was almost the same as that from the shoulder at 176.1 days, but at 212.5 days the muscles of the shoulder had developed 2.3% more than those of the shoulder girdle. The groups of muscles within the shoulder girdle showed little difference in development at either age but within the groups making up the muscles of the shoulder there was greater variation at both ages. In the muscles of the forearm and foot there was even greater variation in the development of the muscle groups of which it was comprised at both 176.1 and 212.5 days.

In the neck, the lateral muscles were considerably later developing than the ventral muscles at 212.5 days, although there was little difference at 176.1 days.

The cutaneus, lying in the subcutaneous fat covering the thorax and neck, showed at 212.5 days the same percentage increase from 148.1 days as longissimus dorsi.

The general picture of the pattern of growth in the muscles was similar to that found in the skeleton. Waves of growth extended up both limbs and posteriorly from the neck towards the centre of the body. The wave of growth moving anteriorly from the pelvic limb moved more quickly than the wave which extended posteriorly and these waves converged in the thorax. This supported the findings of the data for the skeleton but again disagreed with McMeekan's (1940-41) results where he showed the lumbar muscles to be the latest developing.

III Growth of Fat.

The order of development of the main fat depots at 176.1 and 212.5 days was intermuscular fat, followed by subcutaneous fat with perinephric and retroperitoneal fat last. McMeekan (1940-41) also found that perinephric and retroperitoneal was the latest developing, but that intermuscular fat was later developing than subcutaneous fat. Palsson and Verges (1952) however, found that with sheep subcutaneous fat was later developing than intermuscular fat. The divergence between the present results and those of McMeekan with regard to the order of development of subcutaneous and intermuscular fat may be due to intensive selection over the years against subcutaneous fat, resulting in a redistribution of fat between the two depots. It should also be borne in mind that the separation of subcutaneous and intermuscular fat has been a somewhat arbitrary one, based on anatomical position rather than on function.

Within the three subcutaneous fat regions the middle region was the latest developing at 212.5 days followed by the ham and then the shoulder (Fig. 3). As far as these results could be compared with McMeekan's they seemed to be in agreement as to the order of development. However, at 176.1 days, which was more akin to McMeekan's oldest pigs the pattern of development was rather different in that shoulder subcutaneous fat was later developing than ham subcutaneous fat.

Of the major intermuscular fat regions the thorax, abdomen, back and loin region was the latest developing at 176.1 and 212.5 days, followed by the tail and pelvic limb, thoracic limb and neck in that order (Fig.3). Within the tail and pelvic limb the intermuscular fat of the tail, sub-lumbar, hip and thigh was earlier developing than the leg and foot inter-muscular fat at both 176.1 and 212.5 days. This was contrary to McMeekan's findings and to what one might have expected if intermuscular fat development followed the pattern of muscular development. In the forelimb the inter-muscular fat of the fore-arm and foot was later developing than the fat of the upper regions of the limb at 176.1 days but earlier developing than it at 212.5 days. The intermuscular fat of the shoulder girdle was later developing than that of the shoulder and arm at both ages. The intermuscular fat of the fore-limb seemed, therefore, to follow the pattern of muscular development rather more than the hind-limb.

Future Investigations

As has been pointed out these results are preliminary and further analyses are in progress. These will deal, for example, with the use of sample bones and muscles for predicting the total weight and distribution of the skeleton and musculature respectively. Additionally, since the carcasses were subjected to detailed measurements and visual assessments it will be possible to relate these to carcass composition. However, the present study has been confined to a restricted weight range within one sex of a single breed and it is intended to extend the scope of this study to cover a wider weight range in both sexes in several breeds.

Summary and Conclusions

1) The changes in carcass composition in Large White pigs between 150 and 260lb. liveweight have been studied by anatomical dissections.

2) The preliminary results are in broad agreement with results obtained by earlier workers but differ in detail, notably in the order of deposition of the fat depots and the relative rate of development of the musculature and skeleton of the back and loin.

3) There is evidence of secondary waves of growth in the heaviest pigs which was lacking from earlier work in which the pigs were killed at

lighter weights.

4) Further work is needed to cover a wider range in ages and weights with both sexes of different breeds and the effect of experimental treatments, particularly varying nutritional regimes.

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APPENDIX 1

TABLE 1

Relative Growth of Muscle with age expressed as Percentage of Muscle Weight at 148.1 days

MUSCLES OF TAIL, SUBLUMBAR, HIP AND THIGH	148.1 days	176.1 days	212.5 days
TAIL			
Coccygeus	100.0	148.4	193.5
Sacrococcygei	100.0	150.8	235.4
TOTAL	100.0	150.3	227.3
SUBLUMBAR			
Psoas minor	100.0	112.9	145.5
Psoas major & iliacus	100.0	135.1	167.7
Quadratus lumborum	100.0	135.4	170.4
TOTAL	100.0	133.5	166.4
HIP & THIGH			
1) LATERAL			
Tensor fascia lata	100.0	124.4	153.1
Gluteus Medius	100.0	132.3	159.7
Gluteus accessorius	100.0	124.8	152.4
Gluteus profundus	100.0	125.9	153.5
Biceps femoris	100.0	130.1	162.7
Semitendinosus	100.0	132.2	165.7
Semimembranosus	100.0	127.8	158.1
1) TOTAL	100.0	129.5	160.2
2) MEDIAL			
Sartorius	100.0	124.0	156.8
Gracilis	100.0	124.9	155.4
Pectineus	100.0	130.2	159.7
Adductor	100.0	130.3	156.0
Quadratus femoris	100.0	137.4	163.6
Obturator externus	100.0	120.5	138.5
Obturator internus	100.0	129.7	170.9

(Cont'd).

APPENDIX 1 Cont'd

Table 1 Cont'd

Relative Growth of Muscle with age expressed as Percentage of Muscle Weight at 148.1 days

2) MEDIAL cont'd.	148.1 days	176.1 days	212.5 days
Gemellus	100.0	120.0	131.1
2) TOTAL	100.0	128.4	158.0
3) ANTERIOR			
Rectus femoris	100.0	129.1	162.2
Vastus group	100.0	129.5	157.0
3) TOTAL	100.0	129.3	159.1
TOTAL OF 1) 2) & 3)	100.0	129.3	159.7
TOTAL OF TAIL, SUBLUMBAR, HIP & THIGH MUSCLES	100.0	129.8	160.6
MUSCLE OF LEG AND FOOT			
1) DORSO-LATERAL			
Peroneus tertius	100.0	122.3	144.6
Tibialis anterior	100.0	119.7	146.4
Peroneus longus	100.0	121.6	148.5
Long digital extensor	100.0	130.3	157.1
Lateral digital extensor	100.0	121.6	155.1
Extensor hallucis longus	100.0	113.0	134.8
TOTAL 1)	100.0	123.1	150.3
2) PLANTAR			
Gastrocnemius & Soleus	100.0	124.3	149.3
Superficial digital flexor	100.0	124.6	146.6
Deep digital flexor (a, b, & c.)			
a) Tibialis posterior	100.0	121.2	159.1
b) Flexor digitalis longus	100.0	121.3	153.4
c) Flexor hallucis	100.0	119.0	147.7
TOTAL a, b, & c.	100.0	119.5	149.4
Popliteus	100.0	127.7	153.0
TOTAL 2)	100.0	123.4	149.3

TABLE 1 cont'd.

Relative Growth of Muscle with age expressed as Percentage of Muscle Weight at 148.1 days

	148.1 days	176.1 days	212.5 days
3) Metatarsus			
Interossei	100.0	121.4	167.9
Extensor digitalis brevis	100.0	114.3	137.1
TOTAL 3)	100.0	117.5	150.8
TOTAL OF 1), 2), 3).	100.0	123.1	149.6
TOTAL MUSCLE OF TAIL & PELVIC LIMB	100.0	128.9	159.1
MUSCLES OF THORAX, ABDOMEN, BACK AND LOIN			
1) ABDOMEN			
Obliquus abdominis externus	100.0	132.7	168.3
Obliquus abdominis internus	100.0	125.9	155.1
Rectus abdominis	100.0	128.0	157.4
Transversus abdominis	100.0	125.1	154.1
Cremaster externus	100.0	93.0	135.1
TOTAL 1)	100.0	128.3	159.8
2) THORAX			
Levatores costarum	100.0	136.3	176.3
Rectus thoracis	100.0	122.4	162.7
Intercostals	100.0	131.6	170.9
Retractor costa	100.0	186.0	151.2
Transversus thoracis	100.0	138.1	139.9
Diaphragm	100.0	116.6	131.4
TOTAL 2)	100.0	130.1	163.2
3) BACK & LOIN			
Serratus dorsalis posterior	100.0	135.8	187.1
Serratus dorsalis anterior	100.0	120.0	148.6
Longissimus costarum	100.0	133.5	169.9
Spinalis et semispinalis	100.0	133.0	172.1
Multifidus dorsi	100.0	147.7	211.6
Lumbar part	100.0	158.2	223.1
Thoracic part	100.0	138.2	201.2
Longissimus dorsi	100.0	135.3	173.0

APPENDIX 1 cont'd.

TABLE 1 cont'd.

Relative Growth of Muscle with age expressed as Percentage of Muscle Weight at 148.1 days

BACK & LOIN cont'd.	148.1 days	176.1 days	212.5 days
Lumbar part	100.0	134.2	166.5
Thoracic part	100.0	136.1	177.5
Cervical part	100.0	129.9	142.9
TOTAL 3)	100.0	136.2	176.8
TOTAL OF 1) 2) & 3)	100.0	132.8	169.4
MUSCLES OF SHOULDER GIRDLE			
1) DORSAL	100.0	130.9	156.7
2) VENTRAL	100.0	131.2	158.1
TOTAL 1) & 2)	100.0	131.1	157.7
MUSCLES OF SHOULDER			
1) LATERAL	100.0	128.7	158.3
2) MEDIAL	100.0	134.4	166.2
TOTAL 1) & 2)	100.0	130.0	160.0
MUSCLES OF ARM	100.0	130.8	158.1
MUSCLES OF FOREARM AND FOOT			
1) DORSO-LATERAL	100.0	128.6	152.1
2) VOLAR	100.0	119.4	147.0
3) METACARPUS	100.0	125.9	171.4
TOTAL OF 1) 2) & 3)	100.0	123.5	150.1
TOTAL MUSCLE OF THORACIC LIMB	100.0	130.1	157.6
MUSCLES OF NECK			
1) VENTRAL	100.0	132.1	159.0
2) LATERAL	100.0	131.2	171.6
TOTAL 1) & 2)	100.0	131.5	166.9
CUTANEUS	100.0	140.6	173.6
TOTAL MUSCLE OF SIDE	100.0	130.8	162.2

APPENDIX 1 cont'd.

TABLE 2

Age changes in subcutaneous and intermuscular fat in different parts of the side
Relative Growth of Fat with age expressed as Percentage of Weight of Fat at 148.1 days

	148.1 days	176.1 days	212.5 days
Ham subcutaneous fat	100.0	146.4	234.9
Middle subcutaneous fat	100.0	159.0	266.7
Shoulder subcutaneous fat	100.0	152.5	228.1
Total subcutaneous fat	100.0	155.4	251.9
Perinephric and retro-Peritoneal fat	100.0	186.3	328.8
Intermuscular fat of tail, Sublumbar, hip and thigh	100.0	145.3	216.8
Intermuscular fat of leg and foot	100.0	157.6	232.0
Total intermuscular fat of tail and pelvic limb	100.0	147.6	219.7
Intermuscular fat of thorax, Abdomen, back and loin	100.0	157.9	245.0
Intermuscular fat of Shoulder girdle	100.0	146.3	223.2
Intermuscular fat of Shoulder and arm	100.0	139.8	205.7
Intermuscular fat of Forearm and foot	100.0	159.1	196.7
Total intermuscular fat of thoracic limb	100.0	145.6	216.9
Intermuscular fat of Neck	100.0	136.5	198.0
Total intermuscular fat of Side	100.0	148.8	224.2
Total fat of side	100.0	155.9	250.5

TABLE 3

Age changes in some bones in different parts of the side
Relative Growth of Bone with age expressed as Percentage of Weight of Bone at 148.1 days

	148.1 days	176.1 days	212.5 days
Some Bones of Pelvic Limb			
Os coxa	100.0	127.8	150.4
Femur	100.0	121.8	141.5
Tibia-Fibula	100.0	121.9	142.2
Tarsals	100.0	117.7	133.0
3rd. & 4th. Metatarsals	100.0	117.8	132.0
1st. Phalanges	100.0	118.3	139.1
2nd. Phalanges	100.0	118.0	137.7
3rd. Phalanges	100.0	105.7	125.7
Total of Bones of Pelvic Limb	100.0	121.6	141.0
Sacrum	100.0	142.3	157.0
Bones of Thorax and Loin			
1) Lumbar vertebrae	100.0	132.6	161.5
2) Thoracic vertebrae	100.0	135.2	174.2
3) Ribs	100.0	126.3	154.1
4) Sternum	100.0	138.6	123.9
Total of 1) 2) 3) & 4).	100.0	130.7	160.6
Some Bones of Thoracic Limb			
Scapula	100.0	130.4	155.8
Humerus	100.0	121.7	144.2
Radius-Ulna	100.0	125.2	145.0
Carpals	100.0	123.4	139.7
3rd. & 4th. Metacarpals	100.0	117.9	132.8
1st. Phalanges	100.0	120.5	139.5
2nd. Phalanges	100.0	121.6	137.1
3rd. Phalanges	100.0	109.5	127.0
Total of bones of thoracic limb	100.0	123.8	144.7
Cervical vertebrae	100.0	124.5	164.5
Total bones of Side	100.0	125.5	149.6

APPENDIX 1 cont'd

TABLE 4

Age changes in tendon in different parts of the side

Relative Growth of Tendon with age expressed as % of Weight of Tendon at 148.1 days

	148.1 days	176.1 days	212.5 days
Tendon of Pelvic Limb	100.0	104.6	117.7
Tendon of thoracic Limb	100.0	106.4	127.6
Tendon of neck	100.0	133.3	100.0
Total Tendon	100.0	105.4	121.2

Appendix 2

The following rations were fed to all pigs on the experiment:

	50 lb. to 130 lb. liveweight			130 lb. to 260lb. liveweight
		Parts by Weight		
Barley	55	...	...	$67\frac{1}{2}$
Middlings	25	...	...	25
White Fish Meal.	10	...	...	$2\frac{1}{2}$
Lucerne Meal	5	...	...	-
Dec. Ground Nut Meal.	5	...	...	5
To which is added per ton Ground Chalk	$1\frac{1}{2}$	...	...	$1\frac{1}{2}$
Salt	$\frac{1}{2}$	...	...	$\frac{1}{2}$
Vitamin A/D supplement	+	...	...	+
Antibiotic supplement	+	...	...	+

KEY TO THE FIGURES

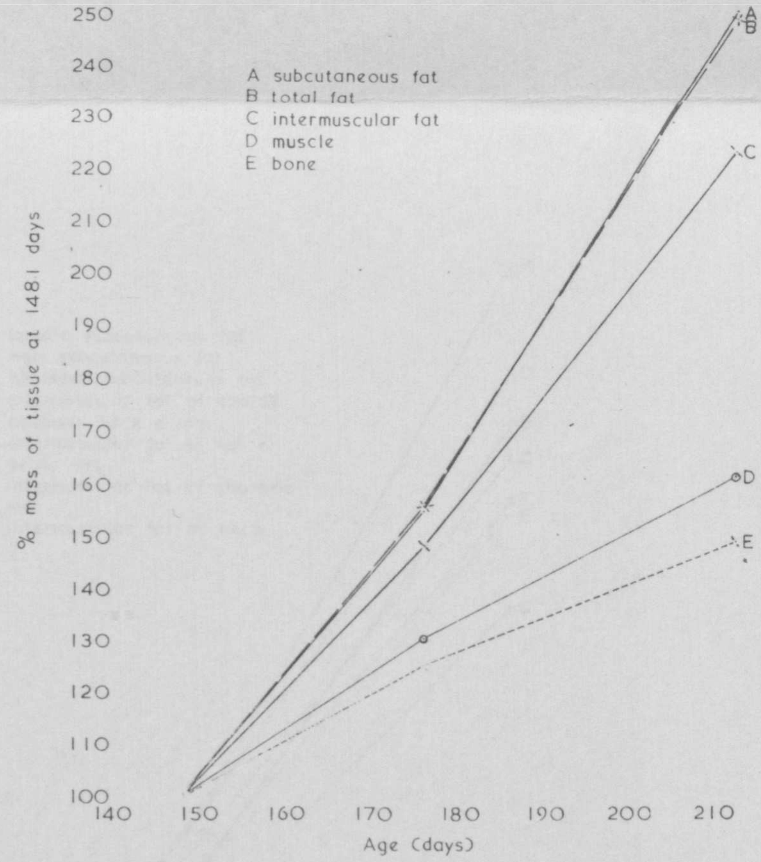
A subcutaneous fat
B total fat
C intermuscular fat
D muscle
E bone
% mass of tissue at 148·1 days
Age (days)

Fig. 1

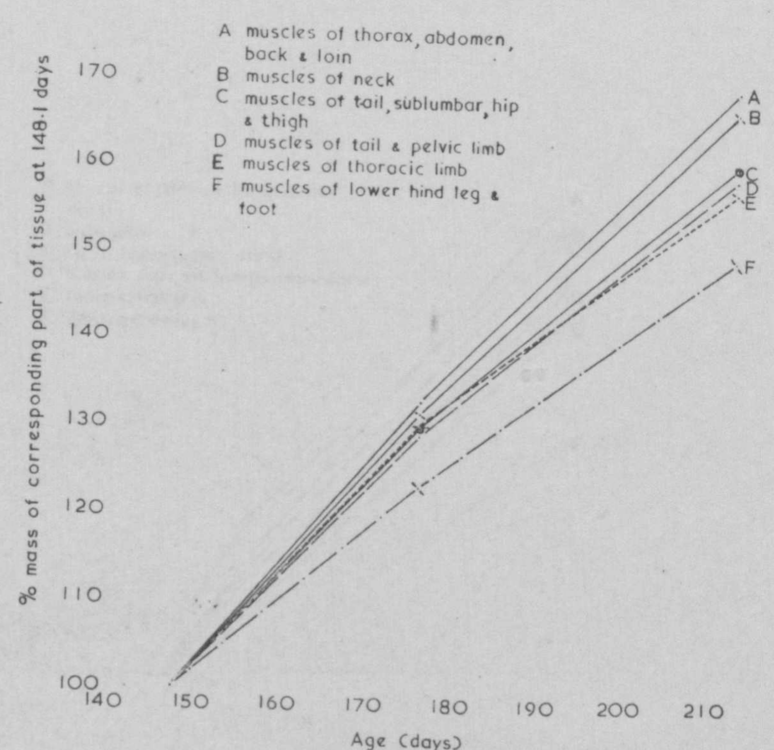
A muscles of thorax, abdomen, back & loin
B muscles of neck
C muscles of tail, sublumbar, hip & thigh
D muscles of tail & pelvic limb
E muscles of thoracic limb
F muscles of lower hind leg & foot
% mass of corresponding part of tissue at 148·1 days
Age (days)

Fig. 2

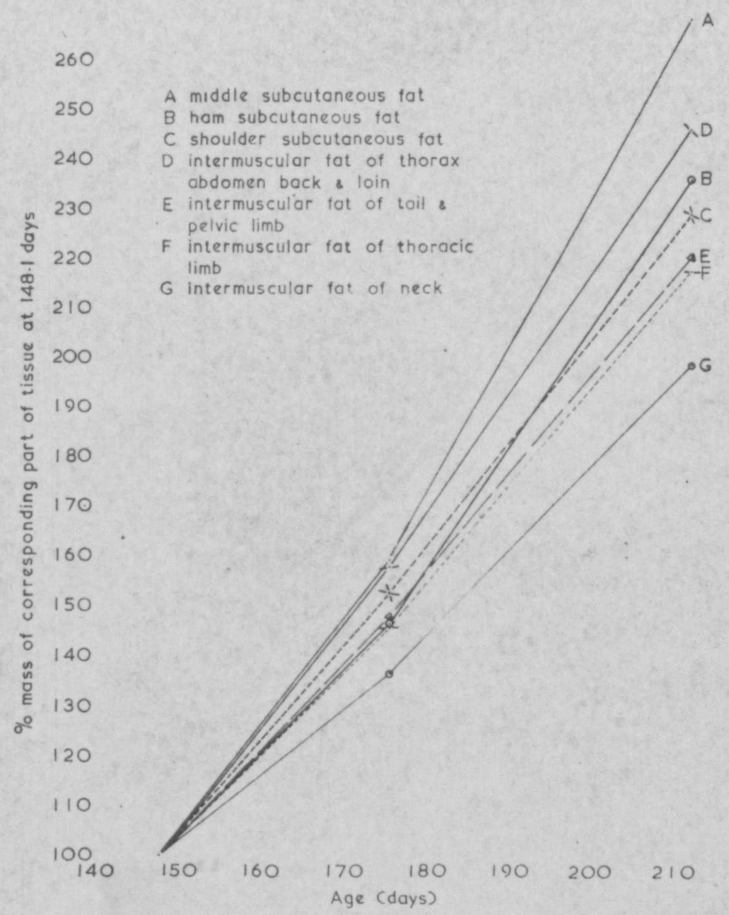
A middle subcutaneous fat
B ham subcutaneous fat
C shoulder subcutaneous fat
D intermuscular fat of thorax abdomen back & loin
E intermuscular fat of tail & pelvic limb
F intermuscular fat of thoracic limb
G intermuscular fat of neck
% mass of corresponding part of tissue at 148·1 days
Age (days)

Fig. 3

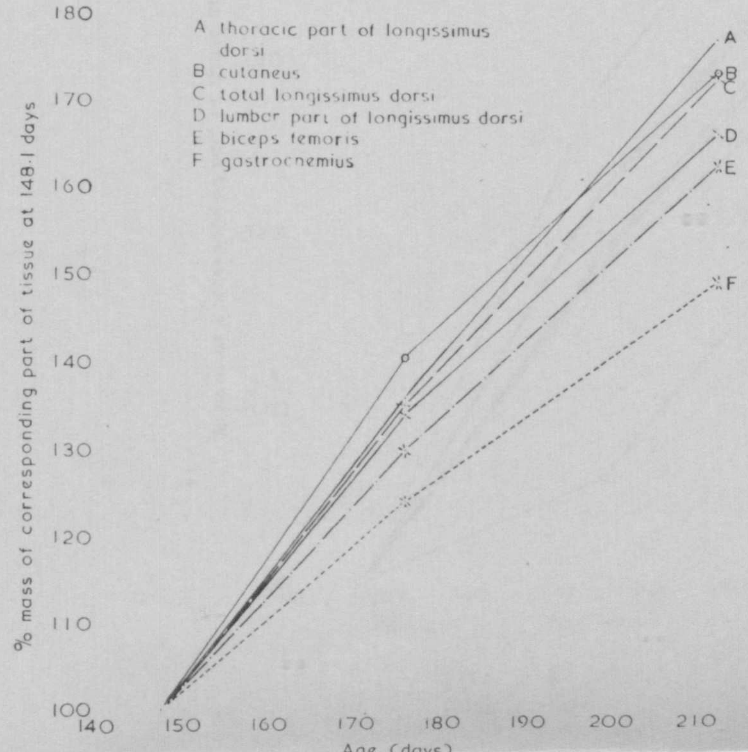
A thoracic part of longissimus dorsi
B cutaneus
C total longissimus dorsi
D lumber part of longissimus dorsi
E biceps femoris
F gastrocnemius
% mass of corresponding part of tissue at 148·1 days
Age (days)

Fig. 4

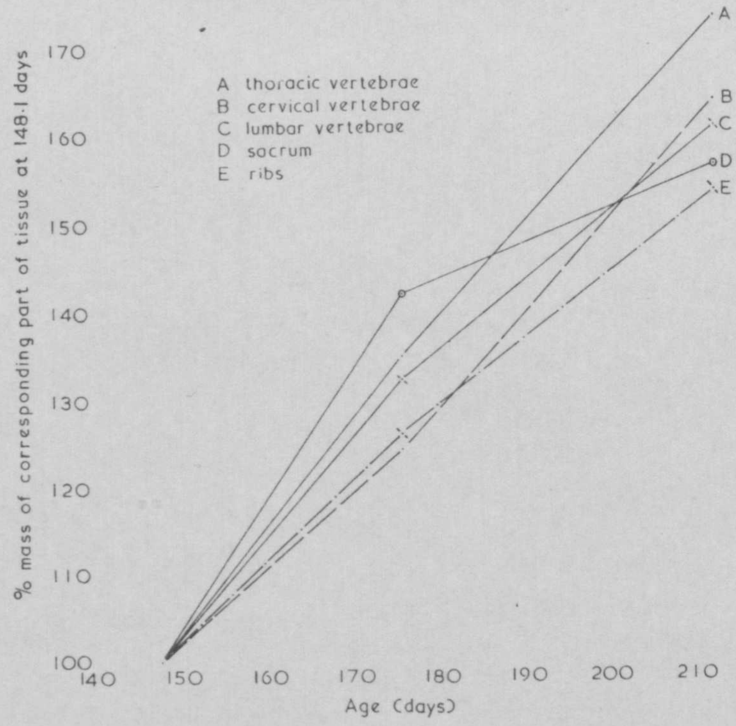
A thoracic vertebrae
B cervical vertebrae
C lumbar vertebrae
D sacrum
E ribs
% mass of corresponding part of tissue at 148·1 days
Age (days)

Fig. 5

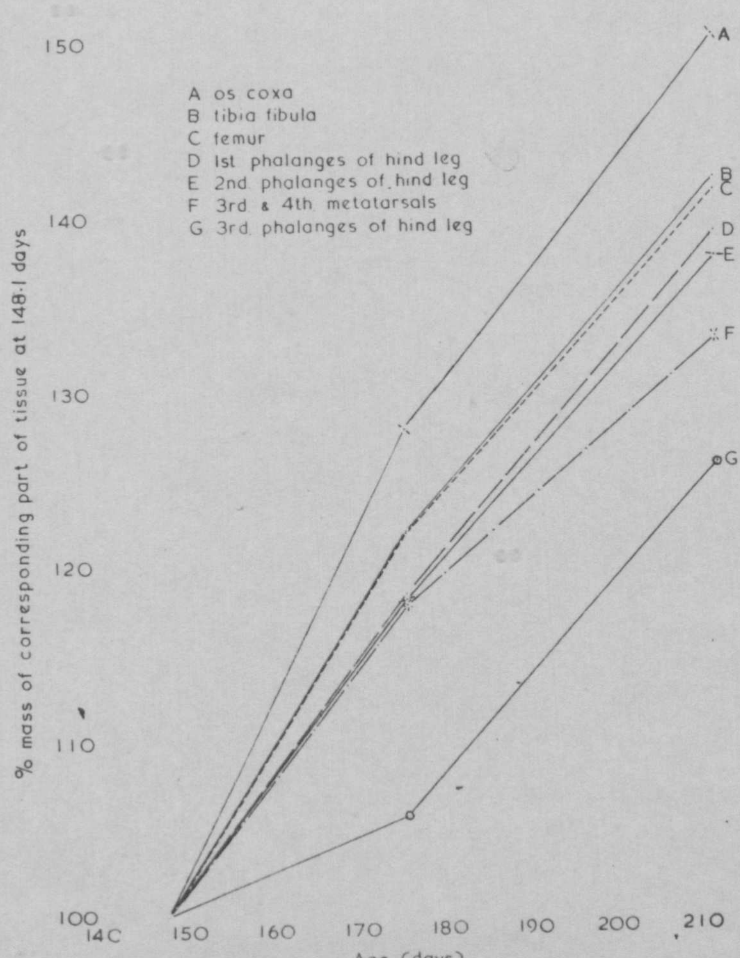
A os coxa
B tibia fibula
C femur
D 1st phalanges of hind leg
E 2nd phalanges of hind leg
F 3rd & 4th metatarsals
G 3rd phalanges of hind leg
% mass of corresponding part of tissue at 148·1 days
Age (days)

Fig. 6