GROWTH AND DEVELOPMENT OF THE SWINE FETUS

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This is to certify that the

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D. E. Ullrey

D. E Ullrey
Major professor

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ABSTRACT

GROWTH AND DEVELOPMENT OF THE SWINE FETUS

I. Measures of body size, organ weights and skeletal development.

II. Time of appearance and quantitative estimation of intestinal lactase and alkaline and acid phosphatase.

by James I. Sprague, Jr.

The objectives of the study were to provide information in two areas concerned with the development of the swine fetus;

1. Measures of body size, organ weight and skeletal development which would promote better understanding of the relationships between the anatomy and physiology of growing fetal structures and which would allow for more accurate estimation of age of fetuses of unknown conception date.

2. Estimation of the time of appearance, location and concentration of intestinal lactase and acid and alkaline phosphatase.

Fetal and newborn pigs were obtained from 19 first-litter Yorkshire gilts which were selected for uniformity of size and age. Supplementary information was gathered from fetuses from 7 Hampshire x Duroc gilts and piglets from 4 Duroc second-litter sows. At appropriate estrous periods, the gilts

were bred to 2 Yorkshire boars, 1 serving a gilt once on the 1st day followed by the 2nd boar on the succeeding day. If further estrus were not observed, the gilts were considered pregnant and caesarian sections were performed 30, 51, 72 or 93 days post-breeding or the gilts were allowed to farrow naturally. The crossbred gilts were slaughtered at 45 days and the fetuses removed from the excised uteri.

Body weights, crown-rump lengths and head widths across the parietal bones were measured immediately after removal from the uterus or just following birth. The weights of internal organs and the lengths of the humeri were obtained immediately subsequent to dissection. The other length measurements were obtained from X-ray photographs and were measures of the calcified diaphyses of the bones of the appendages.

Sections of the gastro-intestinal tract were separated, identified and frozen in dry ice where they were stored until enzyme assays could be performed.

Correlations of litter size with measures of fetal growth were accomplished at each fetal period. Size of litter did not consistently effect the dimension of any particular measure. The data, however, did reveal a smaller proportion of negative correlations for measure versus litter size at 72 days following breeding than in any other fetal period studied or at birth.

Although the differences for most measures between males and females were generally not significant, male fetuses and

male piglets were slightly heavier, longer and the organs heavier at each of the periods.

Means, standard errors of the means and relative standard errors of the means for both sexes and for the sexes combined were presented. Skeletal measures gave smaller relative standard errors than measures of soft tissue or weight of the whole fetus.

Growth patterns plotted from various measurement means of fetal and newborn pigs were presented. Measures of skeleton were generally linear from 51 days to birth. The adrenals made the majority of their growth the last 3 weeks of fetal life.

Correlations of measures of fetal growth with age postbreeding were highly significant. Coefficients of age correlated with measures of skeleton ranged above 0.95 except for head width, while measures of soft tissue ranged from 0.64 to 0.90.

Five estimating equations were suggested for use in predicting ages of fetuses from Yorkshire first-litter gilts. The particular measures selected met several important criteria, which were that they: (1) be easily measured, (2) be consistently duplicated, (3) be highly correlated with fetal age and (4) possess a low relative standard error of the mean at each fetal age. Standard errors of estimate of the predicting equations were all below ± 1.0 day.

At birth, the middle portion of the small intestine possessed a greater enzymatic activity for lactase and alkaline

and acid phosphatase than did the cranial or caudal portions. Acid phosphatase was more uniformly distributed throughout the small intestine than either lactase or alkaline phosphatase except in the cranial duodenum where its activity was lower.

Activity of these 3 enzymes were significantly greater at birth than at any of the fetal periods studied. Alkaline phosphatase activity was also significantly higher at 93 days than at 72 days.

Time patterns for the appearance of alkaline and acid phosphatase which had been reported for other fetal species were confirmed for the fetal pig.

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INTRODUCTION

Technology often stimulates bold changes in current swine management practices. For instance, if the lactation period of a sow could be shortened, additional nutrients now fed the sow during gestation could be eliminated. Advances such as the development of satisfactory milk replacers, excellent baby pig creep rations, as well as control of baby pig diseases have made considerable progress toward weaning of piglets at one month or earlier. If these practices are made feasible, then the sow will not have to be fed during pregnancy for the ensuing lactation period. As a consequence, nutrients fed during late pregnancy could be reduced to a large extent and would be used primarily for the purpose of fetal development.

If the sow does not have to be fed for lactation, but only for fetal development, then nutrition studies of swine pregnancy could place more emphasis on the fetus.

Is it possible to study swine nutrition from the viewpoint of the fetus? Early research of Mitchell et al. (1931) and current research of De Villiers et al. (1958) have accomplished this objective to some degree. However, their studies were only steps toward complete understanding of the nutritional requirements of the fetal pig.

The following study was initiated to add information to this now rapidly developing area of research. The

purposes were not only directed by practical problems of swine husbandry, but by interest in their fundamental biological implications. It was hoped that this study would provide a few more facts for a better understanding of one of nature's more miraculous events - growth and development of the fetus.

The objectives of this study were to provide additional information in two areas:

1. Measures of body size, organ weight and skeletal development which would promote a better understanding of the relationships between the anatomy and physiology of growing fetal structures and which would allow for more accurate estimation of age of fetuses of unknown conception date.
2. Estimation of the time of appearance, location and concentration of intestinal lactase and acid and alkaline phosphatase.

REVIEW OF LITERATURE

1. Body size, organ weight and skeletal development.

Partition of nutrients

Hammond (1944) postulated that the fetus has a priority for nutrients. This concept has been termed by Robinson (Hammond, 1957) the "Theory of Partition of Nutrients." The theory was based on the belief that the nutritional requirements of various tissues of the maternal animal and the fetus were governed by the metabolic rates of these tissues at different stages of development. Hammond suggested that as pregnancy proceeds, competition between the fetus and certain maternal tissues becomes greater, caused in part by decreased fetal metabolic rate.

Barcroft (1946) tested the theory proposed by Hammond. Using the sheep as an experimental animal, he found, as Hammond postulated, that fetal tissues had higher metabolic rates than their maternal counterparts with the exception of muscle and lung. On a dry weight basis, the differences were even greater. However, contrary to Hammond's theory there was not a decrease in metabolic rate of the fetus following the 99th day to term (150 days gestation period in sheep). On a wet tissue basis, Barcroft found an increase in metabolic rate during this period.

Wallace (1948) found fetal tissues, particularly nervous tissue and skeleton, were less effected by low

nutritional level than other tissue. Carlyle (1945) observed, as did Wallace that not all fetal tissues develop at the same rate. Wallace found the following order of organ weight loss relative to the weight of the fetus as a whole in ewes on a low plane of nutrition in late pregnancy:

1. Loss proportionately greater than the whole fetus-

   liver
   fat

2. Loss proportionately to the whole fetus-

   blood vessels
   muscle
   lungs

3. Loss proportionately less than the whole fetus-

   alimentary tract
   bone
   heart
   pancreas
   tongue
   eyes
   nervous tissue

Information on metabolic rates of various fetal tissues at all stages of pregnancy and on several planes of nutrition is considered important in determining nutritional requirements for the sow and for the nutrition of the fetus during development. According to Robinson (Hammond, 1957) "This whole concept is extremely important as it lays emphasis on the probability that the fetus can exercise a demand and is not entirely at the mercy of its environment."

The work of Hammond, Barcroft, Wallace and Carlyle suggested that differences in fetal growth occurring at different periods of fetal development were caused in part by differences in metabolic rates and subsequent partition

of nutients.

Heritability of traits associated with reproductive efficiency of swine

The heritability of traits which measure efficiency of swine reproduction was studied by Cummings et al. (1947). They found the following heritabilities:

Survival from birth to weaning	40%
Size of litter at birth	22%
Total litter weight at birth	36%
Size of litter at weaning	32%
Total weaning weight of the litter	7%

These heritability percentages indirectly suggested the importance of proper environment during both gestation and lactation for economical swine production. Since heritability of litter size and litter weight at birth was quite low, the research worker has a productive area for investigation with promise of important economic advantage as a result of new findings.

Factors affecting fetal weight

Waldorf et al. (1958) studied factors affecting fetal pig weight late in gestation. They found in gilts that age of dam appeared responsible for a greater part of variability in fetus weights than dam's carcass weight or back fat thickness. Condition of the sow, as measured by carcass weight and back fat thickness, did not account for a significant variation in fetus or membrane weights.

In making reciprocal Shetland and Shire crosses in horses and studying the birth weight and placenta weight, Hammond (1944) noted a marked decrease in the size of the

foal from the Shetland dam. Hammond indicated the limitations of the higher rate of the metabolism of the maternal tissues in the small breed than in the large may have been the cause of the decrease in birth weight. Another possible explanation for the decrease in birth weight was a limit of special growth substances of maternal origin.

Hammond (1932) also had shown that single lambs were 28 percent heavier than twins. Wishart and Hammond (1933) noted rabbits with 8 to 11 young per litter averaged 45 grams at birth while in litters of 1 to 2 the weight was 95 grams at birth.

It was therefore evident that size of the litter had an important effect on the growth of the fetus. In swine, this was noted by Mitchell et al. (1931) and De Villiers et al. (1958).

Early pregnancy

McKenzie (1948) emphasized the importance of good nutrition of the gilt and sow during early pregnancy by noting a close relationship between gains in weight of the sow during the 4 weeks following breeding and the number of pigs farrowed.

Self et al. (1955) compared full versus slightly limited rations for Chester Whites and Poland China gilts. He found full feeding during puberty (during the time between first and second estrus) and for 25 days past the second estrus resulted in the most number of ova shed. However, the limited fed group had a greater survival of embryos.

These workers then found the greatest overall efficiency combined the 2 systems. This combination involved limited feeding during the pre-pubertal period, full feeding during the estrous period (the gilts were bred at 2nd estrus) and limited feeding from breeding until the 25th day had elapsed. Self pointed out this data was in agreement with that of Robertson et al. (1951) and Christian and Nofziger (1952) who reported higher ovulation rates and lower embryo survival rates with a "high" level of feeding than with a "moderate" feeding system during the period after breeding.

Haines et al. (1959) in an experiment designed to study the effect of energy intake, found full feeding Duroc-Jersey gilts resulted in more ova shed. The full fed gilts and the limited fed gilts were equal in their fertilization rate in his experiment.

Studies of fetal development in swine

Ullrey in 1954 reviewed the early research including the work of Kiebel (1897), Lowrey (1911) and Warwick (1928). Ullrey pointed out that the work of Kiebel is now of limited value because of changes of breeds, nutrition and type. The usefulness of Lowrey's and Warwick's research is also somewhat limited for these reasons and because sows at that time did not receive gestation rations fortified with trace elements and vitamins as rations are formulated today. Lowrey and Warwick recovered their fetal pigs from slaughter houses and the length of gestation was estimated from crown-rump measures. Lowrey's research was particularly interesting

because of his method of reporting the growth of the fetus. He expressed measures of fetal structure as a percentage of body weight.

Warwick (1928) found fetal weight increased most rapidly during the last 20 days of gestation than earlier while fetal length increased at a nearly uniform rate during the last 20 days of gestation. The variation in fetal weight increased as pregnancy progressed and as litter size became larger. Warwick proposed that the average of all normal subjects rather than measurements of any one individual would give the best estimate of fetal age.

Ullrey (1954) gathered data concerning relative size and development of fetuses removed from sows and gilts. He prepared a "normal" standard of organ weights and skeletal measures and was able to improve the accuracy with which the age of the fetus of unknown conception date could be estimated. The standards also served as a basis for comparing measurements from abnormal fetuses.

Ullrey used the method of least squares to reduce his data to quadratic and cubic polynomials. He described different equations for first-litter gilts and-second litter sows for each fetal measurement. The organ and tissue measures evaluated were weight of body, brain, heart, lung, liver and kidney. X-ray measures were performed of the calcified diaphysis of the humerus, radius, ulna, femur and tibia. Gross measurements included, crown-rump length, head width and dissected humerus length.

Ullrey proposed that it would be desirable to have a single organ or bone which in cases of edema and partial resorption would best represent the growth of the fetus. He found the dissected humerus would satisfactorily meet this objective.

Newland (1955) and Newland and Davis (1961), in a study primarily designed to measure fetal uptake of manganese in swine, observed several factors influencing fetal growth. Newland's observations are summarized below:

(1) Normal subjects were born from low manganese gestation rations containing 6 to 100 parts per million of manganese. Also no effects on fetal weight or phosphorus metabolism were noted from these low manganese diets.

(2) A negative correlation was found between the number of fetuses in the litter and fetal weight.

(3). Radiophosphorus absorption and concentration of inorganic phosphorus was directly proportional to the weight of the fetus.

(4) In early gestation small fetuses had a faster uptake of P^{32} and higher specific activity than larger fetuses.

(5) No significant difference between weight and uterine position was noted in 80 and 110 day fetuses; however, a pattern was noted for 65 day fetuses which indicated the center fetuses in the horn were lighter than at the apex or bifurcation.

Further studies of fetal growth and development were

described by Pomeroy (1960 a,b,c,d,) in his monumental thesis, "Infertility and neonatal mortality in the sow." A comprehensive review of Pomeroy's work follows:

Reasons for disposal of sows

Pomeroy (1960a) from a field survey, found that the two most important reasons for disposal of sows were reproductive failure and piglet mortality. He states, "The latter was known to be a serious problem in commercial pig production, but the short breeding life of sows and the fact that a considerable proportion of them become sterile after only one or two litters does not appear to have been generally recognized." The reasons for slaughtering sows and the percentage of the total as analyzed by Pomeroy are listed in Table 1.

Table 1. Analysis of reasons for slaughtering sows. (Pomeroy, 1960a)

Reason for slaughter	No. of Sows	% of Total
Failure to breed	214	21.4
Piglet mortality	178	17.8
Old age	150	15.0
Low fertility	101	10.1
Disease	75	7.5
Milk failure and udder troubles	61	6.1
Uneven or unthrifty litters	46	4.6
Foot and Mouth disease restrictions	32	3.2
Injury	26	2.6
Giving up pig breeding	26	2.6
Too fat or too big	21	2.1
Labor difficulties	20	2.0
Miscellaneous	50	5.0
Total	1000	100.0%

The above survey was summarized by Pomeroy as follows:

(1) Sixty-four percent of the sow disposal was due

to "failure to breed", "piglet mortality", "old age" and "low fertility".

(2) The average breeding life of 1000 sows was 3.75 litters per sow which agreed closely with earlier work of Donald (1941) who reported an average of 3 or 4 litters in a lifetime. Pomeroy found only two litters per sow was the modal value.

(3) In the sows which failed to breed (21.4 percent), the incidence of reproductive failure was greatest in young females. "Of all the sows discarded as sterile, 30.3 percent were discarded after having had one litter."

(4) The failure to conceive was highest in sows which farrowed at an age of under twelve months.

(5) Sows which farrowed for the first time at 14 to 15 months had a longer breeding life time and produced more pigs per litter and more pigs per sow's lifetime.

(6) Mortality of the baby pigs accounted for 17.8 percent of the sow culling. The average pre-weaning mortality found in 2411 litters was 26.5 percent. Pomeroy noted an unexpected number of litters which had 100 percent mortality of the pigs born. He believed death in these cases was due to "failure of adaption to a post-natal environment because most of the pigs which die are undersized and weakly at birth." He acknowledged the fact that there may be cases where infection kills all pigs, weak ones as well as the thrifty ones.

(7) Low fertility was responsible for culling 10

percent of the sows. In most cases, the animals culled were young sows which produced small litters because of low ovulation rate, or possessed normal ovaries coupled with excessive embryonic death.

(8) Old sows were culled at a modal number of litters of 8 suggesting further management reasons at this time for culling. These reasons might include making room for young sows as well as those reasons mentioned previously, that is, excessive piglet mortality and uneven or unthrifty litters.

Embryonic mortality versus infertility

Pomeroy (1960b) continued, after his initial survey, with several experimental observations in regard to intrauterine physiology of swine and its effect on fetal development.

In one experiment, sows were slaughtered in 2 groups, the 1st at 7 days and the 2nd group at 12 to 21 days after breeding. Subsequent to slaughter the reproductive tracts were removed and examined.

Of the sows with normal ovaries, 7 out of 10 bred 7 days before slaughter were pregnant, but only 4 out of 22 were pregnant when slaughtered between the 12th and 21st day after breeding. This suggested to Pomeroy that the main cause of sterility in sows, with apparently normal ovaries, was embryonic mortality. On the other hand, of sows with apparently abnormal ovaries at slaughter, only one of 19 which had been mated to a fertile boar was

pregnant. This suggested that of sows with abnormal ovaries the main cause of infertility was lack of fertilization.

Fetal development

In another experiment, Pomeroy (1960c) compared data obtained from an inbred herd of Large White pigs at the Animal Research Station, Cambridge, with that from outbred Essex pigs from swine farms of the area. The purpose of the study was to find if growth and development of the fetus in normal and inbred sows could be associated with neonatal mortality. A summary of the experiment follows:

(1) Inbreeding increased preweaning mortality from 30 to 45 percent in the first four generations, from 50 to 68 percent in the 5th to the 9th generation and to 88 percent in the 10th generation of inbreeding.

(2) During the first three days after birth 70.2 percent of all deaths occurred.

(3) The average birth weight of the baby pigs which died the first three days was only 1003.5 grams compared with 1258.5 grams for the surviving pigs. Of the pigs which died within three days, 83.0 percent weighed less than 900 grams at birth. Of the pigs which weighed 1400 grams or more, 18.5 percent died within the first three days.

(4) There was greater mortality during the winter.

(5) Mortality was highest in litters under 5 and over 15, however those litters between 5 and 15 exhibited no increase in mortality up to 15.

(6) High levels of inbreeding in Large Whites

tended to slow fetal growth from mid-pregnancy. When the inbred females were bred to boars of another breed the fetuses grew normally. Pomeroy (1960c) attempted to study this problem further with reciprocal ova transplants between inbred Large Whites and Essex, but was unsuccessful in his attempt.

(7) Both increased fetal age and increased litter size affected fetal weight. Variation of fetal weight between litters could not be demonstrated statistically.

(8) Male fetuses were heavier than females at all stages investigated.

(9) X-ray photographs revealed ossification was more advanced in the largest fetus within a litter when compared to the smallest; however, the appearance of centers of ossification were not delayed in the latter.

The growth curve of outbred fetal pigs from data of 80 outbred litters was found to be the cubic equation:

$$W = \frac{1}{10} (0.2447\ t - 4.06)^3$$

W = average weight of normal fetuses (gm.)

t = stage of pregnancy (days)

Pomeroy transformed the data into an equation used by Huggett and Widdas (1951).

$$W^{1/3} = a(t - t_o)$$

W = fetal weight (gm.)

t = conception age (days)

a = constant (specific fetal growth velocity)

t_o = constant

The formula for the growth curve was the equation:

$$W^{1/3} = 0.1135\ (t-16.59).$$

Pomeroy observed that the constant 0.1135 agreed favorably with the figure of 0.12 suggested by Huggett and Widdas (1951).

Pomeroy further found that there was a slight decrease in average fetal weight with increased litter size only when the litters past the 20th day of gestation were considered. He contended that the effect of litter size on average fetal weight was greatest after the placenta had reached its maximum development and competition began between fetuses.

Hammond (1960) made a similar contention. "In the embryonic stage the embryo size is not affected by the plane of nutrition of the mother for the trophoblastic cells have priority of nutrition from the bloodstream over the maternal tissues." He then proposed that the area of the placenta at the end of the embryonic stage determined what quantity of nutrients the developing animal would receive in the fetal stage. The proposal was based on the theory that the available nutrients during the fetal stage resulted primarily from diffusion between the blood streams of the mother and the fetus.

In addition, Pomeroy found that the relationship between litter size and within litter variation in fetus weight was significant and positive. Variability in fetus weight, therefore, increased with increased litter size. Pomeroy recalled that Warwick (1928) had made a similar conclusion. Pomeroy noted that variability in fetal weights increased after about 60 to 70 days which corresponded to the time when

the placenta had reached its maximum size. Hammond (Parkes, 1952) from experiments with rabbit litters of different sizes, found after the 24th day of pregnancy, that the fetuses began to vary in size. This time corresponded to the time when the rabbit placenta had reached its maximum dimension.

Growth of fetal membranes

The membranes, according to Pomeroy (1960c), grew faster than the fetus until 65 days and then stopped growing or grew only slightly until near term. A second increase in growth rate was noted at 100 days.

Growth of the fetal fluid

Pomeroy (1960c) confirmed Wislocki's 1935 research concerning the growth of the fetal fluids. The allantoic fluid reached its maximum volume at 65 days which indicated, according to Pomeroy, an expansion of the uterus to make room for the growing fetuses. Pomeroy found the increase in allantoic fluid volume was much less rapid in gilts than in sows, and reached a maximum at 75 days compared with 65 days for sows. The maximum was 150 grams of fluid for gilts and 400 grams for sows. There was a greater similarity between gilts and sows in amniotic fluid volume. The amniotic fluid weight was also less variable between fetuses than the allantoic fluid weight.

Growth of uterus, cervix and vagina of sows

Pomeroy (1960c) found that the growth of the uterus was rather complex. The following regression equations were fitted to the data from the 30 to 90 day period post-breeding:

(1) Sows $Y = 21.48\ x_1 + 57.59\ x_2 + 28.03$

(2) Gilts $Y = 21.82\ x_1 + 36.87\ x_2 + 15.30$

Where Y = weight of uterus (grams)

x_1 = stage of pregnancy (days)

x_2 = number of fetuses

This equation suggested that the stage of pregnancy had a similar effect on uterine weight in gilts and sows while the effect of number of fetuses on uterine weight was greater in sows than gilts. Pomeroy said, "The increased growth of the uterus with increasing litter size suggests that overcrowding is not primarily responsible for decreased average weight of fetuses in large litters."

Growth of the cervix and vagina in this study was not significant until the 90th day in gestation. At that time a slight growth in length and appreciable growth in weight and a softening and relaxing of the walls occurred.

Differential growth of the carcass

Pomeroy determined the percentage composition of fetal carcass based on dissection into fetal joints. The dissections were performed according to the method of McMeeken (1940) with minor modifications.

The growth pattern of the anatomical joints indicated a decrease in the percent of head, neck and pelvis; the percent loin and leg increased and the thorax and shoulders as a percentage of total weight tended to remain constant.

The carcass weight of the fetus as a percent of the total fetal body weight increased in the case of the Large

Whites from 73.9 percent at 51 days to 81.8 percent at 97 days and then fell to 78 percent at 110 days. In another group of Large Whites, the value at 51 days was highest (80.4 percent) and then decreased to 76.6 percent at 110 days. The trend continued until birth of the baby pigs. At birth the carcass weight was approximately 75 percent of the body weight.

Growth of the skeleton

The fetuses were divided into skeleton and flesh by dissection. The total skeleton was expressed as a percent of the total carcass weight. The weight of the parts of the skeleton were expressed as percentages of the whole skeleton.

The results, as found by Pomeroy, are briefly stated as follows:

(1) Large Whites had a higher percent of skeleton than Essex. At 110 days (near term) the Large White averaged 25.0 percent vs. 21.9 percent for the Essex. In both breeds this value fell between 51 and 74 days and rose again at 97 days. After 97 days, the percent rose slowly for the Large White and remained almost constant in the Essex.

(2) Weights of the bones of the head, as a percent of total skeleton, fell between 51 days and 74 days then rose again at 97 days with a slight rise to term.

(3) Weight of the cervical vertebrae, as a percent of the total skeleton, remained fairly constant (4.5 to 5.5 percent) from 51 days to term.

(4) Weight of the thoracic skeleton, as a percent of the total skeleton, decreased from 51 to 74 days and then

increased to 97 days, remaining fairly constant until term.

(5) Weights of the lumbar vertebrae, as a percent of the total skeleton, increased between 51 and 74 days then decreased between 74 and 97 days and thereafter remained fairly constant.

(6) Weight of the pelvic skeleton, as a percent of the total skeleton, decreased between 51 days to 74 days and remained level after that.

(7) Weight of the skeletal bones of the legs, as a percent of the total skeleton, increased steadily to term.

Pomeroy suggested that the data indicated the following pattern: "The weight of the skeleton increased less rapidly than the carcass as a whole, so that it became a progressively smaller proportion of it. In so far as the percentage of bone in the Essex fetus was lower than in the Large White there is a suggestion that it had reached a more advanced state of maturity."

Comparison of the largest and smallest fetuses within litters

The development anatomically and chemically of fetal pigs was used by Pomeroy (1960c) as a criterion to test the hypothesis that subnormal birth weight could be used as an index of prematurity. It was his contention that a pig which is less than average weight at birth exhibits characteristics of an earlier fetal age. He compared the smallest with the largest at four periods; 74 days, 94 days, 104 days and 110 days.

Comparisons were made of weights of several measures of the smallest fetus expressed as a percent of the weight of a similar measure of the largest fetus. These ratios of body weight, carcass weight and of several weights of internal organs revealed that the differences between the smallest and the largest diminished toward birth. It was noted that the carcass measurement was more affected than weight of organs, particularly the brain weight which was hardly affected at all.

When the skeletal weight and carcass weight of the smallest fetus of a litter were compared to the largest, the ratio of the weight of the skeleton of the smallest to that of the largest fetus was consistently larger than the ratio of carcass weights except at 110 days, when Pomeroy reported a small difference between the smallest and the largest fetus.

Also the skeleton as a percentage of the carcass weight of the largest fetus indicated a similar pattern in that the skeleton of the larger fetus was generally a smaller part of its carcass than was the skeleton of the smaller fetus as a part of its carcass. From this data Pomeroy said, "----the slower growth of the smallest fetus affects the growth of the skeleton less than the carcass as a whole or, in other words, the growth of the musculature of the carcass was retarded to a greater extent than the skeleton."

As the weight of the total skeleton of the smallest fetus expressed as a percentage of the weight of the skeleton of the largest fetus was increasing during pregnancy the

differential growth of certain skeletal parts was following, in general, a similar pattern. Expressed as a percent of the total weight of the skeleton, the weight of the legs, shoulders, pelvis and loin increased during the period of 74 days until term. The relative weight of the thorax, neck and head remained steady the last three weeks of gestation but decreased slightly during the three week period from 74 to 97 days. In general these differential measurements revealed no great difference between the largest and the smallest fetal pigs when the two sizes were compared at any of the four periods studied, i.e. 74, 97, 108 or 110 days.

Comparisons of the chemical composition of the smallest and largest fetuses were also accomplished. Pomeroy cited the work of Mitchell et al. (1931) who determined percentages of dry matter, calcium, phosphorus and nitrogen within the fetus. Mitchell's work is reviewed later in this review of literature. Pomeroy also cited work of McCance and Widdowson (1954) who had described changes in sodium, potassium and chloride concentration in the fluids of the prenatal and postnatal rat. Newland (1955) and Newland and Davis (1961) also presented data of fetal uptake of manganese and phosphorus.

Pomeroy (1960c) determined the concentration of water, total nitrogen, protein, Cu, Mg, P, Na and K in the fetus from 51 days to birth. The findings were:

(1) Percent of water decreased
(2) Total N percent increased
(3) Protein percent increased

(4) Ca increased markedly (5 times)
(5) Mg increased markedly (2 times)
(6) P increased markedly (3 times)
(7) Na increased slightly
(8) K increased slightly

He found the concentration of potassium somewhat lower in inbred Large Whites than in outbred Essex. Spray and Widdowsen (1951) earlier had determined sodium and potassium content of pigs at birth. They found the concentration of sodium fell and the concentration of potassium rose after birth until a constant was reached. Pomeroy noted the inbred Large Whites were lower in potassium than the Essex in all stages indicating perhaps that the inbred pigs were more immature. There also was a general tendency for the concentration of sodium to fall and potassium to rise. The overall picture was clouded somewhat by a sharp rise in percent sodium and a fall in percent potassium at 108 days to 113 days.

These chemical determinations were applied by Pomeroy to test the hypothesis that smaller fetuses were more immature. He reported that the percent water was lower in the larger fetuses at 108 days and 113 days and the percent of nitrogen was higher in the larger fetuses at all stages. In general, the differences in each case were small and the hypothesis, according to Pomeroy, could not be supported.

Ossification of the skeleton: Pomeroy (1960c) noted that large fetuses not only had larger bones but the fetuses were more advanced in degree of ossification. However, the time of appearance of centers of ossification was not retarded in the smaller fetuses. In early studies of fetal

growth in the rabbit, Appleton (1929) found heavier fetuses possessed more ossification. Wallace (1948) found greater ossification in fetal lambs from ewes on a high plane of nutrition.

Prenatal mortality

Pomeroy (1960d) approached his study of prenatal mortality by using three different measures. These were (1) loss of ova by comparing the number of corpora lutea with the number of fetuses, (2) percent of degenerate fetuses of the total number of fetuses and (3) relationship between ova shed and the loss of ova.

The overall percentage loss of ova expressed, as a percentage of corpora lutea count, was 38.94 percent. Most of this loss had occurred before the end of the 20th day. The loss after 20 days was determined at 10 day intervals. There was no statistical difference noted between any 10 day period from 20 to 89 days; however, the loss between 90 to 113 days was highly significantly different and greater than between 20 and 89 days past breeding. Pomeroy noted his data agreed with Warwick (1928) who indicated that as pregnancy proceeds fetal losses increase.

His second measure was the percentage of degenerate fetuses as compared to the number of fetuses. These data did not show that time and prenatal mortality were related. One reason proposed by Pomeroy was the difficulty of observing fetuses which were undergoing autolysis early in pregnancy. The following table from Pomeroy (1960d) indicates

that the percentage of degenerate fetuses reached a peak at 60 to 69 days.

Table 2. Percent degenerate fetuses[1] (Pomeroy, 1960d)

Stages of pregnancy (days)	Fetuses, percent degenerate
20-29	0.00
30-39	9.21
40-49	4.29
50-59	4.17
60-69	17.71
70-79	7.84
80-89	8.86
90-99	5.97
100-113	7.26
Total	7.67

The third criterion of Pomeroy was the effect of the number of ova shed on the loss of ova. The data from gilts killed during the first 10 days after conception, suggested, "in cases of normal ovulation rates, i.e. up to about twenty, it is rare for only some of the ovum to be fertilized, i.e. all the ova are fertilized or none are fertilized." He noted that, "there were no significant differences in percent mortality with increased ovulation rate between 11 and 22, but there was a significantly greater loss in litters where the ovulation rate was 23-25." This was an exceedingly interesting observation which needs further experimentation to substantiate.

[1] The table is a portion of Table 4, Pomeroy (1960d).

2. Fetal nutrient deposition as a measure of food requirement of pregnancy in swine.

Mitchell et al. (1931), in their classical study of the food requirements of pregnancy in swine, noted the importance of adequate nutrition during late pregnancy. They found that two-thirds of the growth of the fetus occurred during the last four weeks of gestation. Gross energy, crude protein, ash, calcium, phosphorus and iron all progressively increased in rate of depostion during pregnancy. At 16 weeks (near term) the deposition was double the amount at 10 weeks.

Sixteen pregnant gilts were sacrificed starting at five weeks post-breeding to obtain an estimate of the energy needed for gestation. A detailed summary of their observations are listed below:

(1) Gilts in metabolism cages required five pounds of feed per day. Group fed pigs required eight pounds. Both groups were fed to gain 1 to 1.5 pounds per head per day.

(2) After 16 weeks of gestation (112 days), the uterus accounted for 29.8 percent (6 fetuses), 28.1 percent (7 fetuses), or 36.0 percent (10 fetuses) of the live weight gained during pregnancy.

(3) Variability in fetal weights within litters measured by coefficient of variation, decreased from 18.8 percent at 35 days to 3.9 percent at 63 days, then increased to 20 percent at 90 days and remained above 10 percent until 98 days and was irregular from 111 days until term.

(4) Male fetuses were heavier than females by 5.5 ± 1.4 percent after the sixth week.

(5) Dry matter increased regularly from 8.15 to 8.90 percent at 35 days to a range of 16.81 to 17.53 percent at 105 to 112 days.

(6) Ash content of the fetuses on a dry matter basis increased from 12 to 22 percent from the 5th to 11th week with no further increase during the last five weeks.

(7) The calcium concentration of the dry matter increased irregularly up to termination of pregnancy as did the calcium concentration of the ash.

(8) The phosphorus concentration of the dry matter increased irregularly up to term, but its concentration increased even more irregularly than the calcium percent of the ash.

(9) The percentage of iron on a dry matter basis did not show any progressive variation. Liver and spleen iron concentration equaled or was greater than that in the remainder of the fetus near term, which indicated storage of iron.

(10) Fat did not show a progressive increase.

(11) Intrauterine nutrient deposition was determined by the equation:

$$W = kt^n$$

W equals weight of the nutrient deposited in the uterus at the end of each gestation week t. W was expressed in grams except for iron which was in milligrams and gross energy which

was in calories. The symbols k and n were constants to be determined from each set of data. Constants k and n were determined by the method of least squares for total fresh weight of products of conception, total gross energy, total crude protein, total ash, calcium, phosphorus and iron. All the data were corrected to a litter size of eight. The equation which was used to express fetal growth was also used by Murray (1925), MacDowell and Allen (1927) and Mitchell (1929).

(12) Using the first derivative of the above equations a deposition of 312 grams of new material was predicted at the 16th week of gestation (just prior to birth) for a litter size of 8, of which 33 grams would be crude protein, 11.7 grams ash, 4.29 grams calcium, 1.98 grams phosphorus and 12.3 milligrams iron. The caloric content of this material was 272 calories. At the 10th week nutrient deposition rates would be only one-half or less of the rates at 16 weeks.

A more recent paper using similar criteria was published by DeVilliers et al. (1958). Nine gilts, one each at 10 day intervals, from 30 to 110 days post-breeding were used. The following measurements of uterine nutrient deposition were reported: organic dry matter, nitrogen, crude fat, ash, calcium, phosphorus and iron. These measurements were then used to calculate the energy content of the uterus and to prepare feeding standards. A close relationship was found between the size of fetus and the time from conception. Based on

their data and Mitchell's 1931 experiment, the following exponential equation was developed for the deposition of total nitrogen.

$$N \text{ (grams)} = 9.8\ e^{0.031t}$$

$$\text{Log } N \text{ (grams)} = 0.0135t + 0.990$$

$$t = \text{days after conception}$$

These workers found that nutrient deposition increased as an exponential function of time from conception which means "considerable deposition first takes place during the latter part of gestation."

Similar equations were formulated for total deposition of energy, iron, calcium and phosphorus in the products of conception corrected to a litter size of ten. They also presented equations of daily deposition of nitrogen, energy, calcium, phosphorus and iron corrected to a litter size of ten.

On the basis of daily nutrient deposition and by considering the utilization of ingested nutrients and the heat increments of gestation, nutritive requirements for fetal development were calculated and feeding standards were established for the pregnant female.

3. Development of intestinal carbohydrases and acid and alkaline phosphatase in the pig.

Much of the early research regarding the fetal development of digestive enzymes of mammals was reviewed by Needham (1931). Later research was reviewed by Driscoll and Hsia (1958) and Fries (1958). Hartman et al. (1961) surveyed the literature regarding the digestive enzymes of the neonatal pig and the pig through weaning. Driscoll and Hsia's review highlighted the research as applied to human pediatrics, while Fries reviewed enzymal studies of domestic animals, particularly the calf. Fries also reviewed the formulation and utilization of milk replacers for calves, utilization of various carbohydrates and protein sources by calves and baby pigs and the effects of enzyme supplementation of practical calf and baby pig rations.

The following survey of the literature will briefly review the development of the digestive carbohydrases and intestinal phosphatases of the pig. A detailed discussion of the other gastro-intestinal enzymes can be found in the reviews above.

The survey is divided into two main parts which are as follows: (1) neonatal and fetal development of the carbohydrases of the pig and (2) development of intestinal phosphatases.

Neonatal and fetal development of the intestinal carbohydrases of the pig

The following section reviews (1) utilization of carbohydrates by the neonatal pig and (2) carbohydrase activity

of the fetal pig and neonatal pig.

Utilization of carbohydrates by the neonatal pig

Johnson (1949) found glucose or lactose fed in purified diets, beginning at the 2nd day after birth, produced satisfactory growth in pigs. When sucrose was fed, acute diarrhea resulted which led to kidney hemorrhage and death within a short time. Fructose was also found to be unsatisfactory. The inability of the two-day old pig to utilize sucrose had been confirmed by Becker et al. (1954b). Becker and his associates also found glucose or invert sugar produced satisfactory growth and survival rates of pigs from 0 to 9 days. Pigs that received fructose or sucrose lost weight and had a very low survival rate. Diarrhea was severe with the use of fructose and sucrose, less severe with invert sugar and there was none with glucose.

Two studies have been reported in which various carbohydrates were compared for the pig in the period from 7 to 35 days of age. Becker et al. (1954a) found that glucose, lactose, sucrose, dextrin or starch produced about equal gains during this period. Less diarrhea was noted in the groups receiving lactose and starch. Hudman et al. (1955) reported that lactose was superior to glucose, sucrose, corn syrup solids and corn. Corn starch, oat groats, corn flakes and gelatinized starch produced gains considerably lower than lactose.

Using 9 week old pigs Becker and Terrill (1954) found that glucose, sucrose, dextrin and starch produced equal

gains when fed at the rate of 50 percent of the diet. A slight depression in growth occurred when lactose was fed at this rate, but the depression did not occur when the diet was composed of 25 percent lactose.

Cunningham and Brisson (1957a,b) using two-day old baby pigs observed the effects of supplementing various purified starch-containing diets with amylolytic enzymes. Supplemental pancreatic and malt amylases had no effect on growth rate, survival time, or digestibility of raw or cooked starch. Cooked starch was inferior to raw starch as a source of carbohydrate in baby pig diets.

Cunningham and Brisson (1957c) also studied the utilization of maltose by newborn pigs. Through the use of digestion trials and intestinal loop techniques, they found orally ingested maltose was 97.4 percent digested by 2 to 5 day old pigs. The rate of digestion was 0.72 grams per kilogram of body weight per hour. Maltose, injected into a tied-off segment of the small intestine of newborn to 4 day old pigs was digested at the rate of 0.62 grams per kilogram of body weight per hour.

By following the level of the reducing sugars in the blood Dollar and Porter (1957) and Dollar et al. (1957) demonstrated that the young calf and pig cannot utilize maltose, dextrin or starch for the first 4 to 5 weeks of life and sucrose for at least 7 weeks.

Braude et al. (1958a,b) found the beginning of maltose utilization by the pig came at 5 days of age and at that

time the performance was similar to that of glucose when glucose was fed. They also discovered that the 5 to 7 day old pig could begin to utilize solutions of dextrin. Therefore, they concluded that amylase was secreted in effective amounts by pigs of this age. They found that rapid digestion of these food stuffs was important for their assimilation and the process depended on the age of the pig and the solubility of the polysaccharide. They suggested it was possible, therefore, that the action of amylase was complemented by a solubilizing process that was inadequate in the young pig but that developed with age.

Carbohydrase activity of the fetal pig and neonatal pig

Lactase activity: Plimmer (1906) came to the conclusion that lactase was present in adult omnivores and carnivores but not in adult herbivores. Mendel (1906) was not able to demonstrate lactase activity in the adult pig, an omnivore. It was interesting to note that assays of swine intestinal tissues for lactase were not performed again until the 1950's when Bailey *et al*. (1956) found lactase to be present at a high level at birth in the pig. These Canadian workers measured the lactase activity from birth to 50 days of age. The activity was high until 20 days then decreased steadily to a negligible level at 50 days. Heilskov (1951) also found a similar pattern for rabbits and cattle.

Lactase activity was studied by Walker (1959b) in the pig from birth to 5 weeks. When the activity was expressed

per kilogram of body weight per gram of dry tissue, the activity declined rapidly in agreement with the data of Bailey et al. (1956). When the activity was expressed as total lactose hydrolyzed per hour per animal, the amount of lactase present at birth remained at a constant level up to 5 weeks of age. Walker suggested that this indicated a fixed amount of lactase producing tissue was present at birth. Walker said, "It is merely shared out over the length of the intestine as the pig grows." This method of expressing the activity of lactase corrected for the growth of the intestinal tract. He believed it gave a more correct picture of the total amount of enzyme activity present.

Fries (1958) in his review of the development of lactase in human fetuses reported that lactase is rather late in its appearance. It was not reported until the 7th or 8th month and often times was absent in prematures. Mendel (1906) was able to find lactase in the pig embryo, but he did not report the age of the embryos.

Pancreatic amylase activity: Cunningham (1959) stated his belief that more information about digestion of starch by the neonatal pig is necessary to decide whether it is possible to improve the pig's utilization of starch.

Kitts et al. (1956) in a quantitative study using pigs from birth to 37 days found pancreatic amylase activity was approximately 100 units per kilogram of body weight at birth, increased to 1500 units at the 6th day and remained at that level through the 22nd day of age. It had increased to

43,000 units at 37 days. Hudman et al. (1957) and Walker (1959b) also found a similar pattern for this enzyme.

Reports of the occurrence of pancreatic amylase in the fetus appeared to be in conflict according to Fries (1958) and Needham (1931). The presence of pancreatic amylase had been both reported and denied between the 5th and 6th fetal month in the human. It also had been reported as present and absent in the newborn and the one month old human infant.

There were few experiments concerned with amylase in other species. Langendorf (1879) found pancreatic amylase to be present in the 100 millimeter pig embryo and the 250 millimeter bovine embryo. He found the rat fetus and the newborn rat possessed amylase activity, but this activity was absent in the newborn rabbit.

Maltase activity: The importance of the enzyme maltase in swine nutrition is based on the premise that large amounts of amylase are present soon after birth, whereby large amounts of maltose and dextrin are formed from starch. Although in some cases it is believed that maltose can be absorbed intact from the intestine, it is generally accepted that maltose must first be hydrolyzed to glucose (Cunningham, 1959). Therefore, it is self evident that maltase is necessary for maximum utilization of the economically important starchy foods by the post natal pig.

As early as 1906, Mendel reported maltase in the gastro-intestinal tract of the suckling pig. Bailey et al. (1956) reported intestinal maltase activity was very low in the new-

born pig but increased rapidly the first 25 days and remained at that level for 50 days. Cunningham and Brisson (1957b, c), using the ligated intestinal loop technique, found maltose disappeared at a rate of 0.66 grams per kilogram of body weight per hour and was 97.4 percent digested by 2 to 5 day old pigs.

Cunningham (1959), using several techniques including digestion trials and carbohydrate tolerance curves, found maltose was 95.4 percent digestible and the rate of digestion of maltose did not approach the rate of digestion of glucose until the pigs were 7 days old.

Walker (1959b) found maltase in the pancreas increased from low levels at birth to high levels at 5 weeks. Small intestinal maltase, expressed as maltose hydrolyzed per hour per animal, also increased as age progressed. It was previously stated that lactase did not progressively increase when expressed on an animal basis. Walker noted anemia in pigs tended to delay the normal development of maltase producing tissue and the increase in maltase activity was delayed to a later age. Walker suggested that although there appeared to be sufficient amylase at all stages, maltase appeared to be limiting in the early life of the pig.

In the swine fetus, maltase was found to be active very early in fetal development by Mendel (1906); however, he did not indicate the age of the fetus.

Sucrase activity: As noted previously, Becker et al. (1954a,b) and Becker and Terrill (1954) found the neonatal

pig was unable to utilize sucrose until one week old. These experiments were based on digestibility of the sugars and growth data of the pigs.

Enzymatic sucrase assays were performed by Bailey et al. (1956) and Walker (1959b). Sucrase activity was found to be very low from 0 to 10 days and increased to a high level at 5 weeks of age. Mendel (1906) could not detect sucrase in the fetuses of swine.

Gastric acidity: Although not a digestive enzyme, the development of gastric acidity is discussed because of its effect on the reactivity of digestive enzymes. Kvasnitskii and Bakeeva (1940) found that hydrochloric acid did not appear in significant quantities in the pig until 20 to 30 days of age. Lewis et al. (1955) recorded pH values of 4.3, 3.5, 3.9, 3.6, 4.0 and 4.3 on six-hour-fasted baby pigs stomachs at 1, 7, 14, 21, 28 and 35 days of age, respectively. Walker (1959a) followed the formation of NaCl and total acidity of the stomach contents of Large White pigs from birth to 5 weeks of age. The average pH of the duodenum and small intestine was 6.5 and 6.4 respectively. He verified that total NaCl and total acidity in the stomach remained nearly constant from birth to 5 weeks. No free HCl was detected at any age.

Grutzner in 1875 (Fries, 1958) was unable to find acid in the fetal stomachs of cattle, sheep, pigs and dogs. The stage of fetal development was not reported. Moriggia in 1876 (Fries, 1958) reported that the stomach contents of the

bovine fetus were always slightly acid after the 3rd month. Hydrochloric acid was found to be present in the human fetal stomach as early as the 19th week of development (Keen and Hewer, 1929).

Stomach contents of premature infants were often reported to be lower in acid content than the contents of full term infants (Miller, 1941). In general, the acid content was relatively high at birth. It dropped to a low at 10 days of age and then increased.

A pH of 4.4 for the combined contents of the omasum and abomasum of calves at birth was reported by Parrish and Fountain (1952). For the rumen and reticulum, a pH of 6.4 was recorded. Since the omasum does not secrete hydrochloric acid, a somewhat lower pH would be expected if the abomasum had been considered alone.

Occurrence of intestinal alkaline and acid phosphatase

Florence Moog of the Department of Zoology, Washington University, St. Louis, Missouri became interested in the presence and maturity of certain families of enzymes which catalyze the hydrolysis of a single phosphate group. These enzymes are called phosphatases, more correctly phosphomonoesterases. According to Fruton and Simmonds (1958), phosphomonoesterases have been studied extensively, and a number of distinctly different enzymes of this group are known. The best characterized are those in blood plasma, milk, intestinal mucosa and bone. A pH of 9 is optimum for activity of the alkaline variety and a pH of 5 is optimum for the acid

phosphatase. The alkaline phosphatase is further characterized by need for divalent magnesium ions for maximum activity. It is also known that phosphates inhibit its action. In 1944, Moog published the first of several papers discussing the pattern of differentiation of phosphatases of the intestinal tract.

Moog's initial paper in 1944 entitled, "The localization of alkaline and acid phosphatase in the early embryonogenesis of the chick," noted that the phosphatase enzymes accumulated in specific areas including the intestine. This initial study was followed by several papers from 1950 to 1958 all associated with these enzymes and related phenomena.

The evidence presented by the group at St. Louis suggested the following conclusions:

(1) The production of intestinal alkaline phosphatase followed a definite time pattern during development of the chick and mouse (Moog, 1944). The enzyme system was found in the epithelial cells of the intestinal mucosa. In the chick embryo, its level of activity rose 1000 times during the last two and one half days of embryonic life (Moog, 1950). In the mouse, a rise in activity was seen just before birth and just before weaning (Moog, 1951 and Moog, 1953). In the guinea pig the level was slightly elevated in the young animal but soon fell back to the level of the newborn which then persisted during adulthood (Moog and Ortiz,) 1957).

(2) "Physiologically active" glycogen concentration

(Bloom et al., 1951) increased in the intestinal epithelial cells at the same time that the alkaline phosphatase increased (Moog and Wenger, 1952; Moog and Richardson, 1955; Moog and Thomas, 1957).

(3) Acid phosphatase concentration did not increase as markedly as alkaline phosphatase during the fetal period but tended to remain constant (Moog, 1946; Rudnick, 1958).

(4) Adrenal glucocorticoids produced endogenously or injected from an exogenous source produced an earlier appearance of alkaline phosphatase and glycogen. The early increase in alkaline phosphatase equaled the normal maximum of the controls, while glycogen surpassed the normal level of the controls (Verne and Hebert, 1949; Moog and Richardson, 1955; Moog and Thomas, 1957; Moog and Ford, 1957). These data hold true for the chick, the mouse and the rat.

(5) Desoxycorticosterone glucoside produced a weak effect in the stimulation of the earlier appearance of alkaline phosphatase and glycogen as discussed above. This suggested that mineralocorticoids may not have a function in the mechanism in the same way that glucocorticoids stimulated the earlier appearance of alkaline phosphatase and glycogen (Moog and Richardson, 1955).

(6) During the time when the epithelial cells were increasing in their phosphatase content, these cells were also making dramatic changes in microscopic appearance. Under the light microscope they changed from cuboidal and became columnar, with slender elliptical nuclei and with dense

cytoplasmic layers. The cytoplasmic layers appeared first above the nuclei and then basal to the nuclei. The striated borders became composed of neutral polysaccharide on the surface of the lumen. The cytoplasm first became more and then less basophilic and the accumulation of glycogen was transient (Moog and Richardson, 1955; Rudnick, 1958).

(7) Addition of sodium phenyl phosphate substrate after the 16th day to the chick embryo increased the level of the alkaline phosphatase but decreased the level of acid phosphatase. This phenomenon occurred also when tissues were cultured in vitro (Kato and Moog, 1958).

(8) Chick embryos injected with adrenal glucocorticoids were not retarded in growth if the injection was made after the 16th day; the embryos were slightly heavier than the controls, with heavier yolk sacs, which were drawn in a little earlier before hatching than in the controls (Moog and Richardson, 1955).

(9) The alkaline phosphatase was associated with the striated border of the epithelium (Zetterqvist, 1956; Brandes et al., 1956; Puchtler and Leblond, 1958), and possibly was functional in transport of nutrients through the epithelial cell into the blood.

MATERIALS AND METHODS

Experimental subjects

The fetal and newborn pigs were obtained from 19 Yorkshire first-litter gilts. Supporting information was gathered from 4 Duroc second-litter sows and 7 Hampshire x Duroc gilts. The 19 Yorkshire gilts were selected for uniformity of size and age from the Michigan State University swine herd. The Duroc gilts were positive control animals from a vitamin A study. The Hampshire x Duroc gilts were from a study where a progestational hormone was adminstered *per os* to control estrus. The females were all considered normal.

The 19 Yorkshire gilts were divided into 5 groups, based on 21 day intervals starting at the 13th day post-breeding. The 5 periods with the number of gilts and fetuses at each period are listed below:

Yorkshire	30 days	3 litters	32 fetuses
	51 days	5 litters	54 fetuses
	72 days	4 litters	59 fetuses
	93 days	4 litters	51 fetuses
	Term	3 litters	37 pigs
Durocs	Term	4 litters	45 pigs
Hampshire x Durocs	45 days	7 litters	63 fetuses

Feeding

The Yorkshire gilts were self-fed ration 1, Table 3a. The Duroc sows were hand-fed ration 2, Table 3b, and the Hampshire x Duroc gilts were hand fed according to Nellor *et al*. (1961). The rations, in all cases, were considered

Table 3a. Ration 1 - self-fed to Yorkshire gilts

Ingredient	Percent
Corn	67.8
Oats	10.0
Alfalfa meal	10.0
Soybean meal(44%)	11.5
Meat and bone scrap	3.5
Limestone	0.4
Super trace mineral salt	0.5
Dicalcium phosphate + zinc	0.2
Vitamin B-supplement[a]	1.0 lb./ton
Vitamin A and D mix[b]	0.5 lb./ton
B_{12} supplement[c]	1.0 lb./ton

[a] 2 grams riboflavin, 4 grams pantothenic acid, 9 grams niacin and 10 grams choline per pound of supplement
[b] 4,450,980 I. U. Vitamin A and 1,264,074 I. U. Vitamin D per pound
[c] 9 milligrams per pound of supplement

Table 3b. Ration 2 - hand-fed to Duroc sows

Ingredient	Percent
Oats	34.4
Wheat	50.0
Soybean meal (44%)	8.0
Meat and bone scrap	4.0
Dried corn distillers solubles	2.6
Trace mineral salt	0.5
Limestone	0.5
Vitamin B supplement[a]	2.0 lb./ton
B_{12} supplement[b]	1.0 lb./ton
Vitamin D supplement[c]	4.5 gm./ton
Vitamin A supplement[d]	

[a] 2 grams riboflavin, 4 grams pantothenic acid, 9 grams niacin and 10 grams choline per pound of supplement
[b] 9 milligrams per pound of supplement
[c] 142,000 I. U. per gram
[d] 16 milligrams per kilogram body weight daily

nutritionally adequate.

Breeding

At the appropriate estrous periods, the Yorkshire gilts were bred to 2 Yorkshire boars, one boar serving a gilt once on the 1st day followed by a 2nd boar on the succeeding day. Three of the Duroc sows were bred to Yorkshire boars and the 4th to a Hampshire boar and were also bred on 2 consecutive days. The Hampshire x Duroc gilts were bred to Yorkshire boars on 2 consecutive days.

Surgical procedure

The gilts which supplied the fetal pigs were taken from the swine farm to the Michigan State University Veterinary Hospital after being off feed and water for 24 hours. At the hospital, caesarian sections were performed by the staff veterinarians. A state of unconsciousness was produced in the gilts prior to surgery by intravenous administration of thiamylal sodium (Surital sodium[1]) into a marginal auricular vein. Anaesthesia was maintained by further administration of this compound or by ether inhalation.

Manipulation of the fetuses and newborn pigs

Hemostats were used to prevent loss of blood from the fetal umbilical cord prior to weighing. The fetuses and newborn pigs were killed by exsanguination prior to dissection. Table 4 lists the anatomical measurements performed. Body weight, crown-rump length and head width were measured

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[1] Park Davis and Co., Detroit, Michigan

immediately after removal from the uterus or just following birth. The weight of the internal organs and length of the dissected humerus was obtained immediately subsequent to dissection. The other length measurements were from X-rays and involved the calcified diaphyses of the listed bones.

Table 4. Measurements of fetal growth

Weight of-		Length of-	
Body	L. Gonad	Body (c-r)[a]	Ilium[d]
Liver	R. Gonad	Humerus (h-c)[b]	Ischium[d]
Spleen	Thyroid	Humerus (t-c)[c]	Femur[d]
L. Kidney	Heart	Humerus[d]	Tibia[d]
R. Kidney	Lung	Radius[d]	Fibula[d]
L. Adrenal	Brain	Ulna[d]	Calcaneous[d]
R. Adrenal	Pituitary	Metacarpal (3 or 4)[d]	Metatarsal (3 or 4)[d]
		Metacarpal (2 or 5)[d]	Metatarsal (2 or 5)[d]

Width of-
Head

[a] Crown-rump length.
[b] Length, head to condyle.
[c] Length, tuberosity to condyle.
[d] Calcified diaphyses length from X-ray photographs.

Tissues for enzyme analysis

Three fetuses from each of the Yorkshire and Duroc litters were chosen for enzyme analysis. In general the 1st, 3rd and 5th fetuses in the right uterine horn were used. The fetuses were opened by a ventral incision exposing the viscera. The liver and spleen were removed and weighed.

The gastrointestinal tract was removed and divided into stomach, cranial duodenum, caudal duodenum, 3 portions of

the jejunum-ileum, colon and rectum. The pancreas was also removed. Immediately after dissection, the samples were placed in a glass vial, corked tightly and frozen in dry ice.

A small portion of each section was fixed in FAA[1] for histological examination.

X-rays of the fetuses

The subjects were placed on their left side in a natural position directly over X-ray film. The film was protected from light by a paper envelope. Paper towels were placed between the film packet and the fetus to absorb excessive moisture. By placing the animal directly over the film, a nearly identical image of the ossified area of the fetus was produced on the film by the X-irradiation. The amount of irradiation was varied for each litter depending on the thickness of the fetuses.

Length measurements were made of the ossified diaphyses of the long bones.

Organ dissection and organ weights

The internal organs were removed from the animals, dissected free of connective tissue and weighed immediately. The balance used was either a Roller-Smith double pan balance or a Mettler Model B, single pan balance. The choice of balances allowed immediate weighing and the recorded value for each organ was considered a fresh wet weight with minor evaporative losses.

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[1] 80 percent ethanol (95 percent), 15 percent formalin and 5 percent acetic acid.

After the skull cap and meninges were removed from the brain, the spinal cord was severed at the atlanto-occipital articulation and the brain was removed leaving the pituitary *in situ*.

The pituitary was removed with a probe and a sharp scalpel. This gland had definite form early in fetal life, therefore no problems were encountered in its dissection even though it was quite small.

The thyroid was removed by blunt dissection and freed of connective tissue under a dissecting microscope.

The heart was dissected free from the great veins, being careful to leave the auricles of the atria intact. The atria were difficult to distinguish from the veins. The arteries were dissected at the point of emergence from the heart where the color changes from deep red to white.

The lungs were dissected free of the pleural membranes, the trachea and the chief bronchi. This dissection was one of the most difficult to perform uniformly.

The spleen was removed from the surface of the stomach and cleaned of connective tissue with a sharp scissors.

The liver was removed from the fetus, and the gall bladder and the cystic duct were removed from the liver before weighing.

The adrenals were dissected from the animal before the kidneys were removed. The adrenals were cut away from the connective tissue and associated blood vessels by the use of a sharp scalpel. The remaining connective and arterial tissue was removed by the aid of a dissecting microscope.

The kidneys were removed from their retroperitoneal

position, and the arteries, veins and ureters were cut at the hili. The renal capsules were left intact.

The testes were severed from the epididymes and vas deferentia while the ovaries were freed from all encompassing tissue.

Preparation of tissue for enzyme analysis

After several unsuccessful attempts to produce a uniform homogenate of fresh tissue, Thompson (1960) suggested the use of a dental amalgamator. The procedure is outlined below.

Approximately a 1 gram sample or less of thawed wet tissue was weighed directly into a 2 milliliter tared plastic capsule. The tissue in the capsule was shredded with a sharp scissors and weighed again and the tissue adjusted until the sample weighed 1 ± 0.01 grams. After removal to a cold room (2° C.), a small amount of ice water and a hard plastic bead were placed in the capsule. Finally, the capsule was capped with a plastic cap and placed on the dental amalgamator. The tissue was agitated for 3 minutes after which the homogenated tissue was quantitatively removed from the capsule, bead and cap by washing with water and decanting into a calibrated centrifuge tube. Ice water was added to the tube to dilute the original tissue homogenate 10:1. The tissue was then suspended by gentle hand agitation, after which the enzyme suspension was centrifuged in the cold room for 15 minutes in an Ivan Sorvell Type M centrifuge at approximately 3000 rpm. All the tissue samples were diluted

to the same proportions in order to facilitate comparison of the enzyme assays on a wet tissue basis.

When enough tissue remained after sampling for enzyme analysis, a 2nd sample was taken for dry matter analysis. The samples were dried 12 hours in a forced draft oven at 105° C.

Lactase assay

The procedure for the lactase assay was performed according to Colowick and Kaplan (1955) using o-nitrophenyl-β-D-galactopyranoside as a substrate. The procedure was modified to produce a pH of 5.6 using an acetate buffer instead of a buffered medium of pH 7.25 as reported in the literature. The procedure was chosen over the procedures of Hielskov (1951) and Walker (1959) which involved titrimetric techniques. The o-nitrophenyl-β-D-galactopyranoside substrate allowed spectrophotometric analysis of the activity of the enzyme.

The lactase activity on the wet tissue basis was corrected to a dry matter basis and expressed as mM of o-nitrophenol released in 15 minutes per 100 milligrams of dry tissue.

The procedure at all fetal ages and for the newborn pig was performed as follows:

(1) A standard curve for o-nitrophenol was obtained by preparing a working standard of 0.1 mM o-nitrophenol. The optical densities of standard solutions of 0.01 mM to 0.1 mM were measured in a Bausch and Lomb "Spectronic 20"

spectrophotometer.

(2) The reaction mixture for the lactase assay consisted of 3.5 milliliters of a 0.2 M, pH 5.6 acetate buffer (previously determined to be the optimum pH), 0.5 milliliter of 0.01 M o-nitrophenyl-β-D-galactopyranoside and 1.0 milliliter of the enzyme preparation of 1 gram wet tissue per 10 milliliter of water.

Procedure for alkaline phosphatase

The procedure for the intestinal alkaline and acid phosphatase assay was a modification from the clinical procedure commonly used for serum alkaline and acid phosphatase[1]. The modified procedure is as follows:

(1) One milliliter of the alkaline buffered substrate (equal proportions of a pH 10.5, 0.1 M glycine buffer and a p-nitrophenyl phosphate substrate[1]) was pipetted into a test tube. A blank was similarly prepared. The tubes were placed in a 40° C. constant temperature water bath.

(2) Noting the exact time, 0.1 milliliter of the enzyme containing solution was pipetted into the reaction tube. The enzyme containing solutions were diluted to insure an enzyme concentration which would produce products at a rate that could be measured without changing the time of the reaction. The tissue prepared from term pigs was diluted, therefore, 100:1, the 93 day tissue was diluted 10:1 and the 72, 51 and 30 day tissues were not diluted at all.

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[1] "Sigma 104 Phosphatase Substrate", Sigma Chemical Company, St. Louis, Mo. Sigma Tech. Bull. 104. 1958

(3) After 30 minutes, 10 milliliters of 0.02 N NaOH were added to each tube to stop the activity. Mixing was accomplished by inversion.

(4) The optical density was recorded for the sample with the spectrophotometer set at 410 millimicrons and zeroed with the reference blank.

(5) Two drops of concentrated HCl were added to the reaction tube to remove the yellow color due to p-nitrophenol. The new optical density was compared to the original measurement. This reading thus corrected for any interfering color contributed by the tissue homogenate and was subtracted from the 1st.

Procedure for acid phosphatase

(1) One milliter of the acid buffered substrate (equal portions of pH 4.8, 0.9 M citric acid buffer and the p-nitrophenyl phosphate substrate solution[1]) was added to a tube.

(2) Into the substrate and buffer, 0.2 milliters of the enzyme containing extract was pipetted, noting the exact time.

(3) Exactly 30 minutes later the enzymatic action was stopped by adding 4 millliliters of 0.1 N NaOH. The sample was mixed by inversion.

(4) The optical densities of the samples were determined using the Bausch and Lomb "Spectronic 20" set at

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1 "Sigma 104 Phosphatase Substrate", Sigma Chemical Company, St. Louis, Mo. Sigma Tech. Bull. 104. 1958

410 millimicrons using 0.1 N NaOH as a reference blank.

(5) To correct the optical density for color contributed by the tissue homogenate, 0.2 milliliter of diluted tissue extract was added to 5 milliliter of 0.1 N NaOH and its optical density checked against the NaOH reference blank.

RESULTS AND DISCUSSION

Effect of litter size on fetal growth

The purpose of correlating litter size with measures of fetal growth was to determine if litter size reduced the dimension of a particular measure at any of the fetal periods studied. If the correlations were negative, one could presume competition for nutrients from maternal origin had taken place. Two assumptions, which are self-evident, were made. The 1st assumption was that nutrients, during the fetal period, reach the fetus by passage across the fetal membranes; the 2nd assumption was that larger litters compete to a greater extent than smaller litters for these nutrients. Pomeroy (1960c) has suggested that competition for nutrients between fetuses within litters starts after the mid-point of pregnancy when the placenta has reached its maximum size.

The correlations derived from the research reported here are presented in Table 5. Even though no consistent pattern was noted for a particular measure such as height, crown-rump length, bone length or organ weight, it was observed that a greater proportion of the correlations of litter size versus each measure were negative at 4 of the 5 periods studied. The majority of the correlations were negative at 45 days, 51 days, 93 days and birth while at 72 days the majority were positive. The percentage negative correlations at each of the periods studied are presented in Table 6.

Table 5. Correlation coefficients of litter size with measures of fetal growth

Measure[a]	30 Days	45 Days		51 Days		72 Days		93 Days		Birth	
		M	F	M	F	M	F	M	F	M	F
Body wt.	.856**	-.242	-.333	-.339	-.508**			-.119	.230	-.626*	-.463
Crown-rump	.775**	.139	-.390	-.161	-.496**	.256	.400	.241	-.270	-.200	.656
Head width	.710**	.176	.284	.070	-.231	-.241	.090	.388	.337	.303	.555*
Humerus H-C		-.221	.349	-.412	.609**	.330	.553**	.404	.422*	-.541*	.366
Humerus T-C		-.433*	-.273	.332	-.515**	.224	.490*	.425	.453*	.385	.319
Humerus X-ray		-.228	-.342	-.167	-.357	.047	.474	-.204	-.297	-.210	-.495*
Radius		-.288	-.292	-.038	-.446*	.250	.622**	-.397	-.378	.076	-.433
Ulna		-.315	-.263	-.066	-.279	.229	.675**	-.324	-.383	-.224	-.518*
Metacarpal(3-4)		-.925**	-.750*	.097	-.198	.306	.446*	-.352	-.284	-.140	-.492
Metacarpal(2-5)				-.814*	.408	.569	.384	.164	-.425	-.061	-.421
Ilium		-.900**	-.600*	-.128	-.467*	.289	.328	-.163	-.337	.365	.333
Ischium				-.672*	-.418	.350	.304	-.316	-.310	.333	.905*
Femur		-.441*	-.251*	-.116		.310	.606*	-.235	-.291	-.292	-.465
Tibia		-.875**	-.714*	-.190		.345	.621*	-.395	-.317	-.235	.062
Fibula			.600			.283	.342	-.337	-.198	-.188	-.356
Calcaneous						.391	.517*		-.223	-.372	-.498*
Metatarsal(3-4)				.092		.294	.440*		-.252	-.127	-.544
Metatarsal(2-5)						.089	.471*		.129	.053	-.410
Liver wt.				-.504*	-.769**	-.555*	.227	-.033	.135		
Spleen wt.				-.491*	-.472*	-.183	.337	.473	.116	.133	-.695
L. Kidney wt.				.175	-.448*	.047	.417	.384	.083	-.173	.238
R. Kidney wt.				-.030	-.432*				.326	-.305	.326
L. Adrenal wt.				-.659**	-.628**	-.087	.064	-.559*	.041	.330	-.353
R. Adrenal wt.				-.615*	-.599**	.257	-.186	.284	-.059	-.660*	-.388
L. Gonad wt.				-.553*	-.431*	-.516	.344	-.106	-.365		.024
R. Gonad wt.				-.173	-.108	.228	.461*	-.161	-.300		.072
Thyroid wt.				.195	-.286	.013	.468*	-.632*	-.322	-.411	-.355
Heart wt.				.336	-.493*	.117	.381	.071	.098	-.381	-.596
Lung wt.				.144	-.308	-.214	.206	-.497*	-.367	-.109	.057
Brain wt.				.023	.274	.436*	.423*	-.195			.194
Pituitary wt.						-.113	.108	-.438	.052	.394	-.120

* (P<0.05). ** (P<0.01). [a] See Table 8 for details of measurements.

Table 6. Percentage negative correlations of litter size with measures of fetal growth

Period	Percent negative correlations
45 days	77%
51 days	76%
72 days	15%
93 days	60%
Birth	58%

The positive correlations at 72 days, as well as the negative correlations at 93 days and birth could be explained by Pomeroy's theory; i.e. competition between fetuses starts at mid-pregnancy. The larger proportion of negative correlations at 45 and 51 days could not be explained by this reasoning, because low insignificant correlations would be expected before mid-pregnancy.

Means and variability data of litter size at each fetal period are shown in Table 7. Since the number of litters used at each period were limited, no valid conclusion of the effect of time of pregnancy or variability of litter size could be made.

Summary: The correlation of litter size with measures of fetal growth was not appreciably influenced by fetal age. The data did reveal a smaller proportion of negative correlations for the measures at 72 days following breeding than in any other period studied.

Table 7. Mean litter size and variability of litter size

	Days							
	30	45	51	72	93	Birth (Gilts)	Birth (Sows)	Birth (Combined)
Number of litters	3	7	5	4	4	3	4	7
Number of fetuses	32	63	54	59	51	37	45	82
Mean litter size	10.6	9.0	10.8	14.75	12.7	12.3	11.3	10.6
Standard deviation	1.58	1.80	5.54	1.52	1.74	1.23	2.94	2.38
Standard error	0.91	0.69	0.85	0.76	0.87	0.71	1.55	0.85
Relative standard error (%)	8.6	6.9	7.2	9.1	6.8	5.8	13.7	7.2

Effect of sex of the fetus on fetal growth

The data illustrating the relationship of sex of the fetus to fetal growth at each of the periods studied are found in Appendix Tables 3, 4, 5, 6 and 7. Table 8 lists the t values of data obtained from males compared with that derived from females. Sex of the fetus had little effect on fetal growth at any of the fetal periods or at birth, although males tended to be slightly heavier, longer and the organs larger at all periods. Only the fetuses at 45 days exhibited a significant difference between sexes for weight, crown-rump, head width, humerus length measured from head to condyle, and humerus length measured from tuberosity to condyle. Differences were not exhibited at the other periods except in the case of the spleen and the left and right adrenal which were heavier in males than in females at 72 days. The gonads were significantly heavier in males than in females

Table 8. Effect of sex of the fetus on fetal growth at 5 fetal periods - t values of males versus females.

Measure	Days				
	45	51	72	93	Birth
Body weight, gm.	2.1*	1.9	1.2	0.3	0.8
Crown-rump length, cm.	2.5*	1.1	1.1	0.5	1.0
Head width, cm.	2.1*	1.3	1.2	1.6	1.0
Humerus length H-C, cm.	2.4*	0.5	1.3	1.6	1.5
Humerus length T-C, cm.	2.4*	0.9	1.9	0.1	0.7
Humerus length, mm.	1.9	1.2	1.5	-0.6	0.2
Radius length, mm.	0.9	0.4	1.2	-0.3	0.9
Ulna length, mm.	1.6	-0.2	1.1	-0.6	0.0
Metacarpal(3or4), mm.	0.3	0.2	0.9	-0.3	0.7
Metacarpal(2or5), mm.	1.0	0.7	-0.8	-0.3	0.6
Ilium length, mm.	2.0	0.2	1.1	-1.0	0.3
Ischium length, mm.	3.1	0.2	1.2	-0.2	0.6
Femur length, mm.	2.1	0.2	1.2	-0.9	-0.1
Tibia length, mm.	0.6	-0.2	1.7	-0.9	0.8
Fibula length, mm.		0.0	2.1	0.0	0.0
Calcaneous length, mm.			2.1	0.0	-0.1
Metatarsal(3or4), mm.	-0.3	-0.5	1.1	0.2	-0.4
Metatarsal(2or5), mm.			1.6	0.3	-0.3
Liver weight, gm.		0.3	1.5	-0.1	0.0
Spleen weight, mg.		0.4	2.4*	0.1	0.1
L. Kidney weight, gm.		-0.1	0.3	0.3	0.3
R. Kidney weight, gm.		0.4	1.6	0.3	0.4
L. Adrenal weight, mg.		0.4	2.6*	-0.5	0.2
R. Adrenal weight, mg.		-0.3	4.4*	0.3	0.6
L. Gonad weight, mg.		3.7**	6.5**	5.1**	164.0**
R. Gonad weight, mg.		3.0**	7.1**	4.8**	147.9**
Thyroid weight, mg.		0.2	1.0	4.4**	0.2
Heart weight, gm.		0.5	1.4	0.0	0.9
Lung weight, gm.		1.1	1.7	-0.9	0.1
Brain weight, gm.		0.7	0.9	0.0	3.0
Pituitary weight, mg.		2.7	1.4	-1.1	2.2

* (P<0.05). ** (P<0.01).

at all periods.

Summary: Although the differences were generally not significant for the effect of sex, the male fetuses and piglets tended to be slightly heavier, longer and the organs heavier at each of the periods.

Effect of fetal age on fetal growth

Means, standard errors of the means and relative standard errors of the means.

Mean values, standard errors of the means and relative standard errors of the means at each fetal period and at birth are included in the Appendix Tables. The data are presented as follows:

Appendix Table 1. Development of the pig at birth (Yorkshire gilts)

Appendix Table 2. Development of the pig at birth (second litter sows)

Appendix Table 3. Development of the pig at birth (combined)

Appendix Table 4. Development of the fetal pig at 93 days

Appendix Table 5. Development of the fetal pig at 72 days

Appendix Table 6. Development of the fetal pig at 51 days

Appendix Table 7. Development of the fetal pig at 45 days

Appendix Table 8. Development of the fetal pig at 30 days

These tables list the means, standard errors and relative standard errors of the means (RSE) for males and females at each fetal period. Since the effect of sex, as previously stated, was not significantly different, the data for males and females were combined. Means, standard errors and RSE's were then calculated for the combined data.

The relative standard error of the mean (RSE) was expressed as the percentage which the standard error comprises of the mean. Snedecor (1953) described a similar method of evaluating standard deviations. The term when applied to standard deviations was called "coefficient of variation" by Snedecor. Since the relative standard error of the mean (RSE) in this experiment was expressed as a percentage, the degree of variation existing in one measure can be readily compared with another.

These RSE values were therefore used to evaluate measures of fetal growth by ranking the RSE of several measures from smaller to larger. The higher ranking measures and their RSE are listed in Table 9. Also Appendix Table 1 through 8 list each measure and its respective RSE. These rankings indicated that skeletal measures were more precise indicators of age than whole body weight or weight of individual organs. In general, RSE of measures of a single dissected bone ranked as well as RSE of crown-rump length; however, at 45 days crown-rump length was superior to either dissected humerus or measures of calcified diaphyses as indicators of age.

Summary: Means and standard errors of the means for males and females were reported for each fetal period. Since sex had little effect, data of males and females were combined and overall means, standard errors of the means and relative standard errors of the means were reported for the combined data. Skeletal measures produced smaller relative standard errors of the mean than measures of soft tissue or

weight of the whole fetus.

Growth patterns

The patterns of growth as indicated by several of the measures of fetuses and piglets from Yorkshire 1st-litter gilts are presented in the following tables and figures.

Table 4 lists the anatomical measures performed. The procedures for the measurement of the organs and tissues were discussed previously in the section entitled Materials and Methods.

Table 10 lists the means of the measurements at each fetal period.

Figure 1 graphically illustrates the changes in body weight, head width and crown-rump length as the pig develops.

Figure 2 illustrates the development of the brain, liver and lungs. Note that the lungs increased in weight only slightly from 93 days to birth.

Figure 3 shows the change in length of the calcified diaphyses of certain bones of the fore limbs.

Figure 4 depicts the same change in the bones of the rear limbs. Note that all skeletal measures were linear with age.

Figure 5 illustrates the development of the heart and kidneys plus the dissected humerus (total length measured from tuberosity to condyle). Note again that this skeletal measure was nearly linear with age.

Figure 6 shows the change in weight of the spleen, and male and female gonads. The spleen and female gonads were

Table 9a. Comparison of relative standard errors of the mean at birth - from Yorkshire gilts

Measure	RSE	Rank
Head width	0.4	1
Brain weight	1.9	2
Humerus (H - C) length	2.3	3
Crown-rump length	2.9	4
Humerus (X-ray) length	3.5	5
Humerus (T - C) length	3.6	6,7,8 (tie)
Ulna (X-ray) length	3.6	6,7,8 (tie)
Femur (X-ray) length	3.6	6,7,8 (tie)
Radius (X-ray) length	3.7	9
Fibula (X-ray) length	4.0	10
Body weight	4.1	11

Table 9b. Comparison of relative standard errors of the mean at birth - from second litter Duroc sows

Measure	RSE	Rank
Humerus (H - C) length	1.2	1,2 (tie)
Radius (X-ray) length	1.2	1,2 (tie)
Femur (X-ray) length	1.3	3
Head width	1.4	4,5 (tie)
Fibula (X-ray) length	1.4	4,5 (tie)
Humerus (T - C) length	1.5	6,7,8 (tie)
Humerus (X-ray) length	1.5	6,7,8 (tie)
Tibia (X-ray) length	1.5	6,7,8 (tie)
Ulna (X-ray) length	1.9	9,10 (tie)
Metatarsal (3 or 4) length	1.9	9,10 (tie)

Table 9c. Comparison of relative standard errors of the means at birth - combined data of Yorkshire gilts and second-litter Duroc sows

Measure	RSE	Rank
Humerus (H - C) length	1.3	1,2 (tie)
Ulna (X-ray) length	1.3	1,2 (tie)
Humerus (T - C) length	1.4	3,4 (tie)
Radius (X-ray) length	1.4	3,4 (tie)
Humerus (X-ray) length	1.5	5,6 (tie)
Femur (X-ray) length	1.5	5,6 (tie)
Head width	1.6	7,8 (tie)
Brain weight	1.6	7,8 (tie)
Fibula (X-ray) length	1.7	9
Metatarsal (3 or 4) (X-ray) length	1.8	10

Table 9d. Comparison of relative standard errors of the means at 93 days - from Yorkshire gilts

Measure	RSE	Rank
Humerus (H - C) length	0.3	1
Head width	0.7	2
Crown-rump length	0.9	3
Humerus (T - C) length	1.2	4,5 (tie)
Ulna (X-ray) length	1.2	4,5 (tie)
Ischium (X-ray) length	1.3	6
Ilium (X-ray) length	1.4	7,8 (tie)
Femur (X-ray) length	1.4	7,8 (tie)
Tibia (X-ray) length	1.5	9
Pituitary weight	1.6	10

Table 9e. Comparison of relative standard errors of the means at 72 days - from Yorkshire gilts

Measure	RSE	Rank
Humerus (T - C) length	0.1	1
Humerus (H - C) length	0.8	2,3 (tie)
Radius (X-ray) length	0.8	2,3 (tie)
Head width	0.9	4
Crown-rump length	1.2	5,6 (tie)
Humerus (X-ray) length	1.2	5,6 (tie)
Brain weight	1.3	6,7,8,9,10 (tie)
Ulna (X-ray) length	1.3	6,7,8,9,10 (tie)
Femur (X-ray) length	1.3	6,7,8,9,10 (tie)
Tibia (X-ray) length	1.3	6,7,8,9,10 (tie)

Table 9f. Comparison of relative standard errors of the means at 51 days - from Yorkshire gilts

Measure	RSE	Rank
Head width	0.5	1
Humerus (H - C) length	0.7	2
Crown-rump length	1.0	3
Humerus (T - C) length	1.3	4,5 (tie)
Humerus (X-ray) length	1.3	4,5 (tie)
Femur (X-ray) length	1.4	6
Ulna (X-ray) length	1.5	7
Tibia (X-ray) length	1.6	8
Radius (X-ray) length	1.8	9
Heart weight	2.4	10

Table 9g. Comparison of relative standard errors of the means at 45 days - from crossbred first litter gilts

Measure	RSE	Rank
Crown-rump length	2.4	1
Head width	2.6	2
Humerus (T - C) length	3.1	3
Humerus (H - C) length	3.2	4
Ulna (X-ray) length	5.9	5
Humerus (X-ray) length	7.3	6,7 (tie)
Radius (X-ray) length	7.3	6,7 (tie)
Femur (X-ray) length	8.3	8
Body weight	8.7	9
Tibia (X-ray) length	10.2	10

Table 9h. Comparison of relative standard errors of the means at 30 days - from Yorkshire gilts

Measure	RSE	Rank
Crown-rump length	1.2	1
Head width	2.9	2
Body weight	3.3	3

Table 10. Fetal growth - Yorkshire first-litter gilts

Measure	Days				
	30	51	72	93	Birth
Body weight, gm.	1.50	49.85	220.5	616.9	1040.9
Crown-rump length, cm.	2.49	9.83	16.3	22.9	29.4
Head width. cm.	0.68	1.91	3.15	4.17	4.55
Humerus length H-C, cm.		1.40	2.44	3.88	5.15
Humerus length T-C. cm.		1.53	2.64	4.14	5.35
Humerus length, mm.		7.7	16.5	29.2	39.5
Radius length, mm.		5.6	12.1	19.9	27.3
Ulna length, mm.		6.5	14.8	26.0	37.4
Metacarpal(3or4), mm.		1.8	5.1	9.6	15.3
Metacarpal(2or5), mm.		1.1	3.6	5.7	9.5
Ilium length, mm.		5.3	12.6	20.9	27.5
Ischium length, mm.		2.4	8.5	15.2	20.0
Femur length, mm.		6.8	15.9	28.4	38.8
Tibia length, mm.		6.4	15.2	27.0	34.6
Fibula length, mm.		5.0	13.1	22.8	32.3
Calcaneous length, mm.		---	5.0	10.9	17.5
Metatarsal(3or4), mm.		1.6	5.5	10.6	16.8
Metatarsal(2or5), mm.		---	3.8	6.9	10.6
Liver weight, gm.		3.13	6.44	14.18	24.90
Spleen weight, mg.		17.48	200.09	832.	781.
L. Kidney weight, gm.		359.	1093.	2369.	3658.
R. Kidney weight, gm.		369.	1059.	2268.	3607.
L. Adrenal weight, mg.		9.28	24.23	40.8	126.9
R. Adrenal weight, mg.		9.23	20.50	38.4	109.0
L. Gonad weight, M. mg.		12.79	34.42	85.8	320.5
L. Gonad weight, F. mg.		9.35	20.22	43.3	27.4
R. Gonad weight, M. mg.		9.99	33.20	84.6	293.9
R. Gonad weight, F. mg.		9.85	18.82	42.3	29.0
Thyroid weight, mg.		9.91	56.82	126.9	177.4
Heart weight, gm.		0.42	1.56	4.07	6.90
Lung weight, gm.		0.12	5.99	16.89	17.09
Brain weight, gm.		1.98	9.25	22.3	35.1
Pituitary weight, mg.		2.8	9.1	18.9	28.0

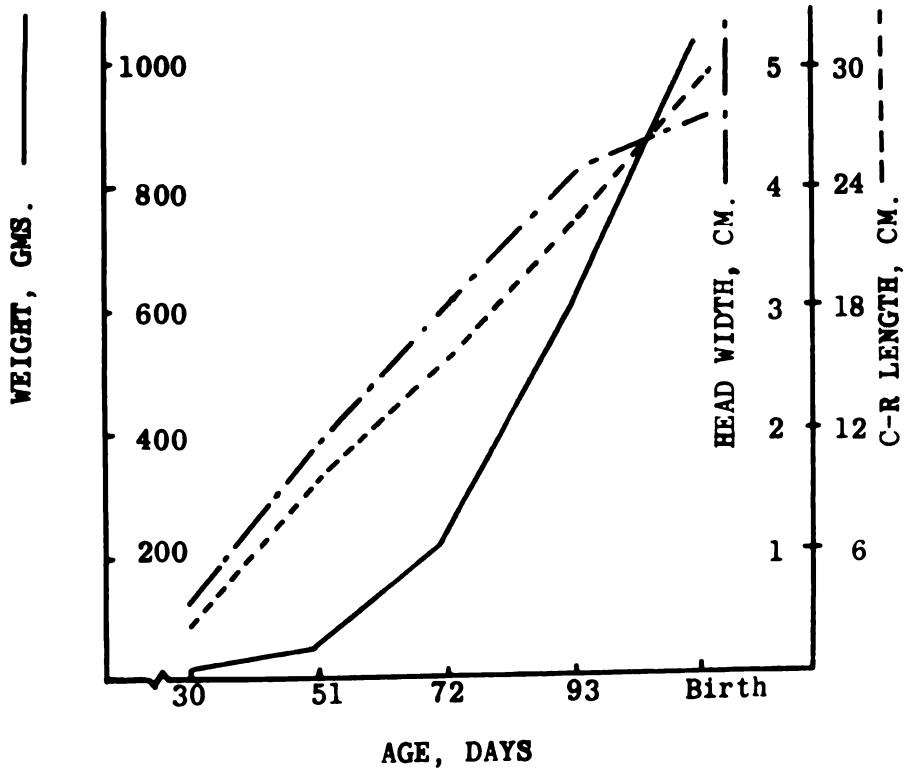

Figure 1. Growth patterns of Yorkshire fetal pigs - Weight, crown-rump length, head width.

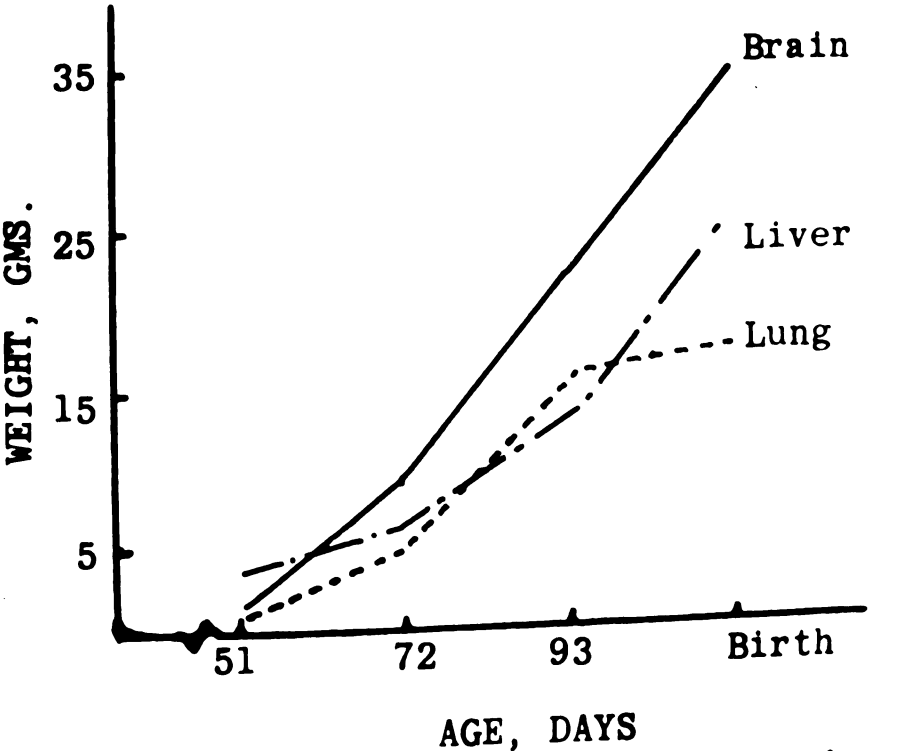

Figure 2. Growth patterns of Yorkshire fetal pigs - Brain, liver, lung.

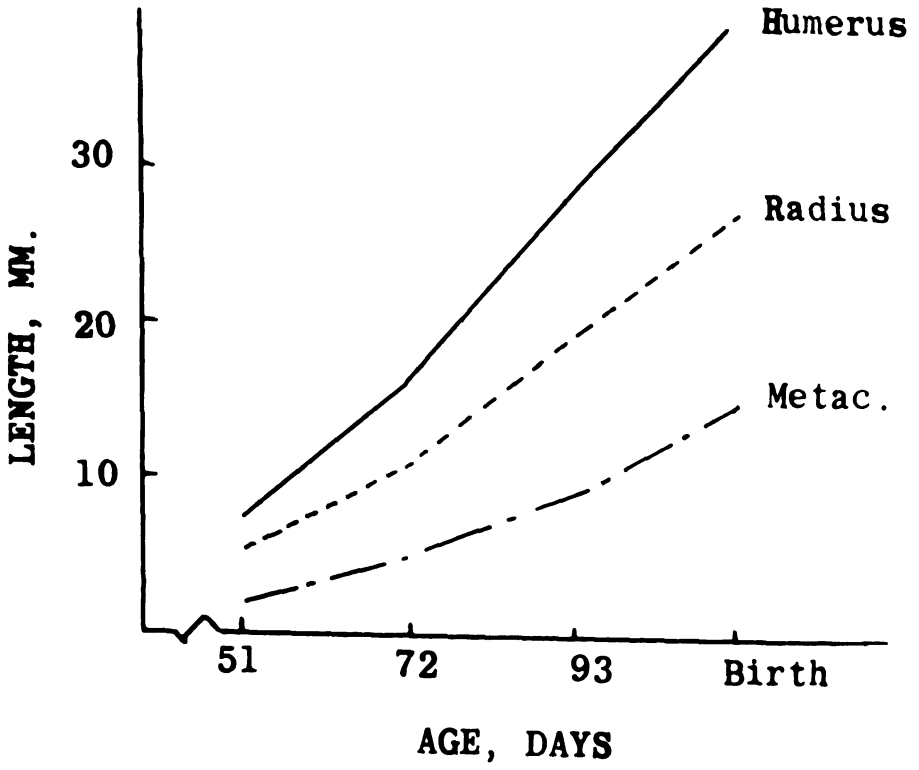

Figure 3. Growth patterns of Yorkshire fetal pigs - Humerus, ulna, radius, metacarpal (3 or 4 and 2 or 5).

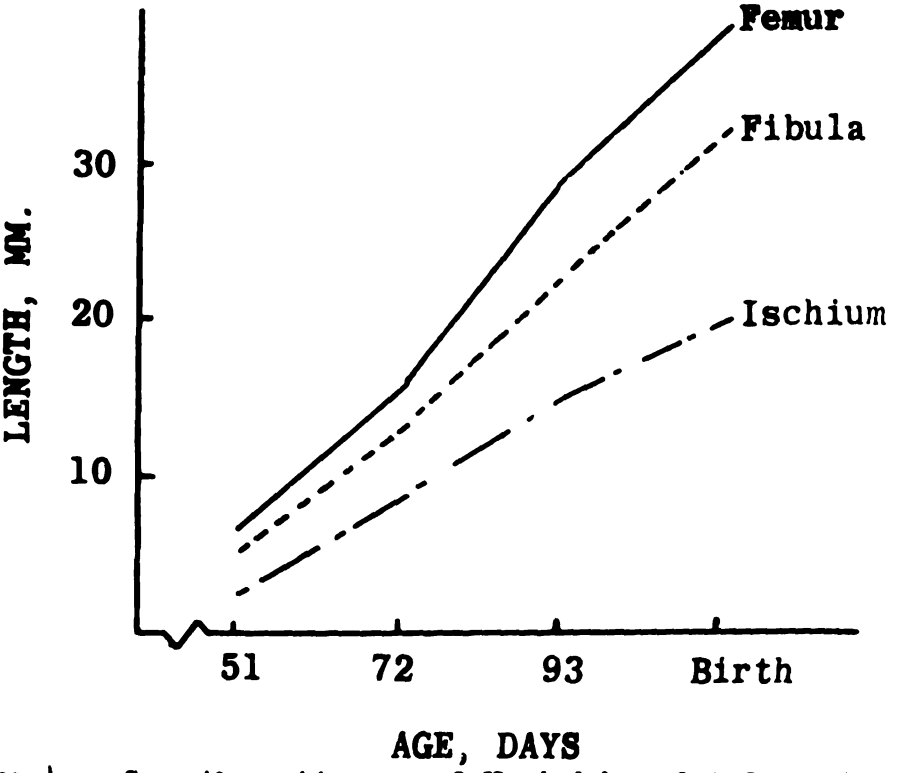

Figure 4. Growth patterns of Yorkshire fetal pigs - Femur, tibia, fibula, ilium, ischium, calcaneous metatarsal (3 or 4 and 2 or 5).

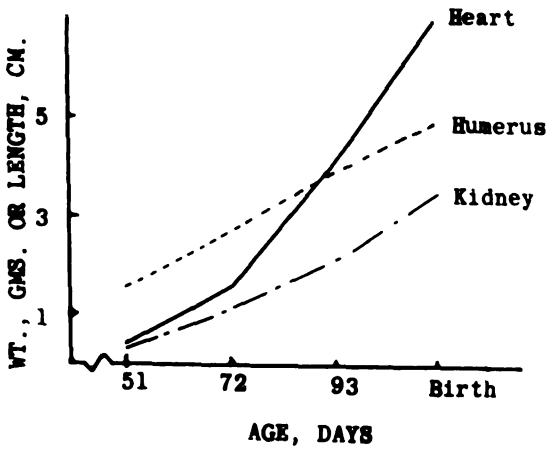

Figure 5. Growth patterns of Yorkshire fetal pigs - Heart, humerus (tuberosity to condyle), humerus (head to condyle) and left and right kidneys.

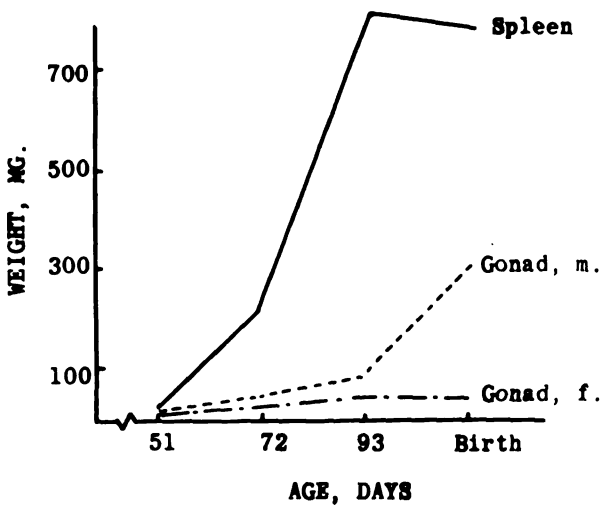

Figure 6. Growth patterns of Yorkshire fetal pigs - Spleen, left and right gonad of the male, left and right gonad of the female.

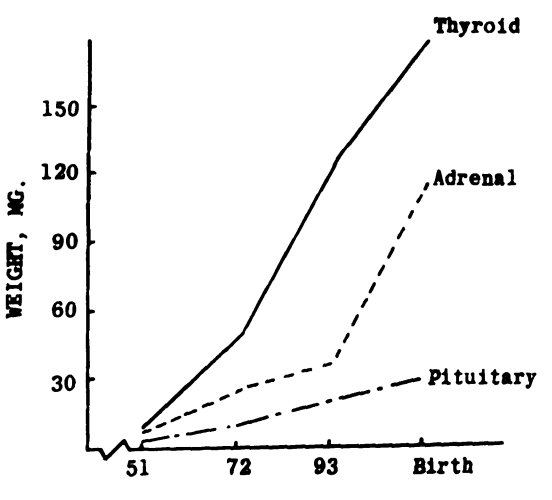

Figure 7. Growth patterns of Yorkshire fetal pigs - Thyroid, left and right adrenal and pituitary.

lighter at birth than at 93 days.

Figure 7 depicts the development of the thyroid, adrenals and pituitary. The growth of the thyroid and pituitary were nearly linear from 51 days to birth. The adrenals increased appreciably in weight the last 3 weeks of the gestation period.

Summary: Growth patterns of fetal development of Yorkshire fetuses were determined for measures of growth of the skeleton and organs. The growth pattern for measures of the skeleton were generally linear with age from 51 days to birth. The adrenal made a considerable increase in weight the last 3 weeks of fetal life.

Correlation of measures with fetal age

Correlations of certain representative measures with age for the data from Yorkshire gilts are presented in Table 11. All coefficients presented were highly statistically significant; however, measurements which represented length of certain portions of the skeleton were more highly correlated with age *in utero* than were measures which represented soft tissue growth. For example, correlation coefficients of well over 0.95 were established for the skeletal measures, except head width, while correlation coefficients of 0.64 to 0.90 were found for soft tissue weights.

Even though one would expect that the weights of the organs illustrated would be highly related to age, the author did not expect high correlation for both calcified and soft tissues. Previous experience suggested that any circumstance

Table 11. Correlations of age with measurements of fetal growth[a]

Measure and period of study	r
Body weight (30 days to birth)	.830
Crown-rump length (30 days to birth)	.984
Head width (30 days to birth)	.804
Length of ---	
Humerus, H-C (51 days to birth)	.983
Humerus, T-C (51 days to birth)	.983
Femur, X-ray (51 days to birth)	.980
Humerus, X-ray (51 days to birth)	.977
Weight of ---	
Liver (51 days to birth)	.754
Spleen (51 days to birth)	.830
L. Kidney (51 days to birth)	.898
R. Kidney (51 days to birth)	.903
L. Adrenal (51 days to birth)	.677
R. Adrenal (51 days to birth)	.799
L. Gonad, female (51 days to birth)	.643
L. Gonad, male (51 days to birth)	.773
R. Gonad, female (51 days to birth)	.667
R. Gonad, male (51 days to birth)	.795
Thyroid (51 days to birth)	.906
Heart (51 days to birth)	.828

[a] Data of fetuses from Yorkshire gilts at 30 days, 51 days, 72 days and 93 days post-breeding and at birth.

resulting in temporary or prolonged inanition would cause a quantitative change from normal in soft tissue much more quickly than in the skeleton. It is suggested then, that either measurement of a single dissected long bone or of an X-ray of a long bone would serve as a better estimate of age than measures of soft tissue.

Historically, estimations of fetal age of animals of unknown conception date had been based on crown-rump length. It is suggested that there are several reasons why this measurement may be somewhat undependable even though correlations with age in this study were very high. First of all, repeat measurements were nearly impossible to exactly duplicate because of changes in body position and errors were thus more likely than when measuring a single bone or weighing an animal or a single organ. The crown-rump measurement involved soft as well as skeletal tissue which may vary considerably in quantity between fetuses of the same age. However, measurement of crown-rump was a simple measure to perform, and secondly, its measurement early in fetal life could be accomplished easier than dissection of an organ or bone. Also, the calcification of the diaphyses of the long bones at 30 days was not sufficient to permit their use that early in fetal life.

Summary: Correlations of fetal age with measures of fetal growth were highly significant. Values for skeletal measures, except for head width, ranged above 0.95, while correlations with measures of soft tissue including weight

of the whole fetuses ranged from 0.64 to 0.90.

Predicting fetal age from fetal growth data

Predicting equations suitable for estimating ages of fetuses from length of bones and the crown-rump length are presented. Accompanying each equation is the correlation of the measure with age and the standard error of estimate for the equation.

The equations were derived from data of fetuses from first-litter Yorkshire gilts. The measures selected for development of these equations met several important criteria. First of all, the measures were easy to obtain; secondly, they were consistently duplicated; thirdly, the measures were of skeletal growth which possessed a higher correlation with age than measures of the soft tissues; and fourthly, the measures possessed low relative standard errors of the means at each of the fetal ages.

The following equations describe bone growth of the fetal pig from 51 days post-breeding to birth:

Humerus (tuberosity to condyle, dissected).

$$y = 29.00 + 1.576x$$

x = length of dissected humerus, mm.
y = age, days

$$r_{y \cdot x} = 0.98$$
$$s_{y \cdot x} = 0.90$$

Humerus (head to condyle, dissected).

$$y = 31.31 + 1.640x$$

x = length of dissected humerus, mm.
y = age, days

$r_{y.x} = 0.98$
$s_{y.x} = 0.80$

Humerus (calcified diaphysis, X-ray).

$y = 40.15 + 1.87x$

x = length of calcified diaphysis, mm.
y = age, days

$r_{y.x} = 0.98$
$s_{y.x} = 0.88$

Femur (calcified diaphysis, X-ray).

$y = 41.60 + 1.87x$

x = length of calcified diaphysis, mm.
y = age, days

$r_{y.x} = 0.98$
$s_{y.x} = 0.77$

The following equation represents the changes of the crown-rump measurement from 30 days following conception to birth:

$y = 21.07 + 0.311x$

x = length from crown-rump, mm.
y = age, days

$r_{y.x} = 0.98$
$s_{y.x} = 0.73$

Summary: Five estimating equations were suggested for predicting ages of fetuses from Yorkshire, first-litter gilts. The measures used for developing estimating equations were selected because they were; (1) easily measured, (2) readily duplicated, (3) highly correlated with fetal age and (4) possessed a low relative standard error of the mean at each fetal period. Standard errors of estimate of the predicting equations were all below ±1.0 day.

Estimation of time of appearance, location and quantity of intestinal lactase and alkaline and acid phosphatase

The distribution of intestinal lactase and alkaline and acid phosphatase at birth as determined in this study is summarized in Table 12.

Assays revealed that the cranial half of the duodenum and the caudal 3rd of the jejunum-ileum were significantly lower ($P<0.05$) in lactase activity than the other portions of the gastro-intestinal tract when the data were examined using the Studentized range test. Therefore, the middle portions of the small intestines exhibited more lactase activity than the tissue near the stomach or colon. The stomach and colon did not exhibit lactase activity at any of the fetal periods.

A similar pattern was noted for alkaline phosphatase activity at birth. The results showed that the activity was significantly less in the entire duodenum and in the caudal 3rd of the jejunum-ileum than in the cranial and middle 3rds of the jejunum-ileum. Again, there was no activity in the stomach or colon.

Acid phosphatase assays of tissue from these 5 areas of the small intestine revealed a similar tendency, but only the cranial portion of the duodenum was significantly lower in acid phosphatase activity than the other areas. There was no acid phosphatase activity in the stomach and colon.

Although there were significant differences in distribution in the small intestine of the 3 enzymes when studied

Table 12. Enzyme distribution - birth

	Lactase[a]	Alk. Phos.[b]	Acid Phos.[b]
Duodenum, Cran.	.19	41	5.8
Duodenum, Caud.	.38	87	8.0
Jej.-Ileum, Cran.	.36	145	9.8
Jej.-Ileum, Mid.	.36	174	9.4
Jej.-Ileum, Caud.	.25	58	9.4

[a] mM o-nitrophenol released in 15 minutes per 100 milligrams of dry tissue.

[b] mM p-nitrophenol released in 30 minutes per 100 milligrams of dry tissue.

Table 13. Fetal development of lactase, alkaline and acid phosphatase activity

Age (days)	%D.M.	Lactase[a]		Alk. Phos.[b]		Acid Phos.[b]	
		n	$\bar{x}$	n	$\bar{x}$	n	$\bar{x}$
30		3[c]	.20	3[c]	4.4	3[c]	5.8
51	13.4	6	.20	7	2.6	7	6.6
72	13.8	35	.10	33	2.4	36	5.1
93	14.5	27	.24	23	8.0	25	5.8
Birth	17.2	51	.31	53	104.6	53	8.8

[a] mM of o-nitrophenol released in 15 minutes per 100 milligrams of dry tissue.

[b] mM of p-nitrophenol released in 30 minutes per 100 milligrams of dry tissue.

[c] Pooled data of 8 fetuses of 3 litters.

at birth, the area differences in enzymatic activity were not significant at 93 days except for lactase which was significantly lower in the duodenum than the jejunum and ileum (Appendix Table 10). At 72 days the duodenum and caudal third of the jejunum-ileum were lower in alkaline and acid phosphatase activity than the cranial and middle portions of the jejunum-ileum (Appendix Table 11). The activity for lactase at 72 days also indicated a similar pattern, however the differences were not significant.

Table 13 illustrates the change in mean intestinal enzyme activity with age. These means include all 5 areas of the intestine. In each case, for the 3 enzymes studied, the activity at birth was significantly greater than the values at 93 days. Also, alkaline phosphatase activity was significantly greater at 93 days than at 72 days. The increase in activity from 93 days to birth for lactase was 1.3 fold, for alkaline phosphatase was 13 fold and for acid phosphatase was 1.5 fold.

The appearance of alkaline phosphatase followed a pattern similar to that reported by Moog for the chick embryo and mouse fetus (Moog, 1950; Moog, 1951; Moog and Wenger, 1952; Moog, 1953). Acid phosphatase activity in this study did not increase as rapidly as that of alkaline phosphatase which was similar to findings reported by Moog (1958).

A complete record of the intestinal enzyme assays performed in this study may be found in Appendix Tables 9, 10, 11, 12 and 13.

Summary: At birth the caudal half of the duodenum and the cranial two-thirds of the jejunum-ileum possessed greater lactase and alkaline phosphatase activity than did the remainder of the gastro-intestinal tract. Acid phosphatase was more uniformly distributed through out the small intestine than either lactase or alkaline phosphatase, but activity was significantly less in the cranial duodenum.

The enzymatic activity was significantly greater at birth than at any of the fetal periods for lactase, alkaline phosphatase and acid phosphatase. Alkaline phosphatase activity was also significantly higher at 93 days than at 72 days.

Time patterns for the rise in activity of alkaline and acid phosphatase, which had been reported for other fetal species, were confirmed for the fetal pig.

SUMMARY

The objectives of this study were to provide information in 2 areas concerned with the development of the swine fetus;

1. Measures of body size, organ weight and skeletal development which would promote better understanding of the relationships between the anatomy and physiology of growing fetal structures and which would allow for more accurate estimation of age of fetuses of unknown conception date.

2. Estimation of the time of appearance, location and concentration of intestinal lactase and acid and alkaline phosphatase.

Fetal and newborn pigs were obtained from 19 first-litter Yorkshire gilts which were selected for uniformity of size and age. Supplementary information was gathered from fetuses from 7 Hampshire x Duroc gilts and piglets from 4 Duroc second-litter sows. At appropriate estrous periods, the gilts were bred to 2 Yorkshire boars, 1 serving a gilt once on the 1st day followed by the 2nd boar on the succeeding day. If further estrus were not observed, the gilts were considered pregnant and caesarian sections were performed 30, 51, 72 or 93 days post-breeding or the gilts were allowed to farrow naturally. The crossbred gilts were slaughtered at 45 days and the fetuses removed from the excised uteri.

Body weights, crown-rump lengths and head widths across the parietal bones were measured immediately after removal

from the uterus or just following birth. The weights of internal organs and the lengths of the humeri were obtained immediately subsequent to dissection. The other length measurements were obtained from X-ray photographs and were measures of the calcified diaphyses of the bones of the appendages.

Sections of the gastrointestinal tract were separated, identified and frozen in dry ice where they were stored until enzyme assays could be performed.

Correlations of litter size with measures of fetal growth were accomplished at each fetal period. Size of litter did not consistently affect the dimension of any particular measure. The data, however, did reveal a smaller proportion of negative correlations for measure versus litter size at 72 days following breeding than in any other fetal period studied or at birth.

Although the differences for most measures between males and females were generally not significant, male fetuses and male piglets were slightly heavier, longer and the organs heavier at each of the periods.

Means, standard errors of the means and relative standard errors of the means for both sexes and for the sexes combined were presented. Skeletal measures gave smaller relative standard errors than measures of soft tissue or weight of the whole fetus.

Growth patterns plotted from various measurement means of fetal and newborn pigs were presented. Measures of

skeleton were generally linear from 51 days to birth. The adrenals made the majority of their growth the last 3 weeks of fetal life.

Correlations of measures of fetal growth with age post-breeding were highly significant. Coefficients of age correlated with measures of skeleton ranged above 0.95 except for head width, while measures of soft tissue ranged from 0.64 to 0.90.

Five estimating equations were suggested for use in predicting ages of fetuses from Yorkshire first-litter gilts. The particular measures selected met several important criteria, which were that they; (1) be easily measured, (2) be consistently duplicated, (3) be highly correlated with fetal age and (4) possess a low relative standard error of the mean at each fetal age. Standard errors of estimate of the predicting equations were all below $\pm$1.0 day.

At birth, the middle portion of the small intestine possessed a greater enzymatic activity for lactase and alkaline and acid phosphatase. Acid phosphatase was more uniformly distributed throughout the small intestine than either lactase or alkaline phosphatase except in the cranial duodenum where its activity was lower.

Activity of these 3 enzymes were significantly greater at birth than at any of the fetal periods studied. Alkaline phosphatase activity was also significantly higher at 93 days than at 72 days.

Time patterns for the appearance of alkaline and acid

phosphatase which had been reported for other fetal species were confirmed for the fetal pig.

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Appendix Table 1. Development of the fetal pig - measures at birth
(Data from first-litter Yorkshire gilts)

Measure	N	ΣX	$\bar{X}$	ΣX^2	S.E.	RSE
Body weight, gm.	35	36432.1	1040.9	40092816.35	42.7	4.1
Crown-rump length, cm.	10	293.5	29.4	8675.43	.86	2.9
Head width, cm.	10	45.51	4.55	207.5043	.02	0.4
Humerus length H-C, cm.	10	51.47	5.15	266.2489	.12	2.3
Humerus length T-C, cm.	10	53.54	5.35	289.9888	.19	3.6
Humerus length, mm.	10	399.0	39.5	15799.00	1.40	3.5
Radius length, mm.	10	273.0	27.3	7543.00	1.00	3.7
Ulna length, mm.	10	374.5	37.4	14193.25	1.36	3.6
Metacarpal(3or4), mm.	10	153.0	15.3	2381.00	0.66	4.3
Metacarpal(2or5), mm.	10	95.0	9.5	926.50	0.52	5.5
Ilium length, mm.	10	275.0	27.5	7775.50	1.53	5.3
Ischium length, mm.	10	200.0	20.0	4237.50	1.62	6.0
Femur length, mm.	10	388.5	38.8	15272.25	1.41	3.6
Tibia length, mm.	10	346.0	34.6	13118.00	3.50	10.1
Fibula length, mm.	10	323.0	32.3	10591.00	1.32	4.0
Calcaneous length, mm.	10	175.0	17.5	3115.50	0.76	4.3
Metatarsal(3or4), mm.	10	167.5	16.8	2850.75	0.70	4.2
Metatarsal(2or5), mm.	10	106.5	10.6	1163.75	0.58	5.4
Liver weight, gm.	10	249.05	24.90	7350.2817	2.90	11.6
Spleen weight, mg.	10	7811.00	781.00	6506187.	66.	8.5
L. Kidney weight, gm.	10	36585.	3658.	142951799.	377.	10.3
R. Kidney weight, gm.	10	36069.	3607.	137448927.	289.	8.0
L. Adrenal weight, mg.	10	1269.1	126.9	167871.63	8.7	6.9
R. Adrenal weight, mg.	10	1090.1	109.0	135647.95	17.0	15.5
L. Gonad weight, M., mg.	6	1922.8	320.5	668514.38	41.7	13.0
L. Gonad weight, F., mg.	4	109.7	27.4	3102.45	2.8	10.2
R. Gonad weight, M., mg.	6	1763.6	293.9	559911.68	37.2	12.7
R. Gonad weight, F., mg.	4	116.0	29.0	3538.30	2.7	9.3
Thyroid weight, mg.	10	1774.0	177.4	356150.22	21.4	12.1
Heart weight, gm.	10	69.04	6.90	498.4708	0.48	6.9
Lung weight, gm.	10	170.93	17.09	3143.2169	1.60	9.4
Brain weight, gm.	10	350.84	35.08	12347.7574	0.65	1.9
Pituitary weight, mg.	10	279.5	27.95	8041.83	1.60	5.7

Appendix Table 2. Development of the fetal pig - measures at birth
(Data from second-litter Duroc sows)

Measure	N	ΣX	$\bar{X}$	ΣX^2	S.E.	RSE
Body weight, gm.	21	26808.0	1276.6	35397168.80	52.8	4.1
Crown-rump length, cm.	6	176.5	29.4	5209.82	0.77	2.6
Head width, cm.	21	108.62	5.17	565.07	0.07	1.4
Humerus length H-C, cm.	21	109.25	5.20	570.18	0.06	1.2
Humerus length T-C, cm.	21	115.58	5.50	639.12	0.08	1.5
Humerus length, mm.	20	824.0	41.2	34102.00	0.63	1.5
Radius length, mm.	21	609.5	29.0	17742.25	0.35	1.2
Ulna length, mm.	21	809.0	38.5	31282.50	0.75	1.9
Metacarpal(3or4), mm.	21	318.5	15.2	4888.25	0.33	2.2
Metacarpal(2or5), mm.	21	196.0	9.3	843.50	0.46	4.9
Ilium length, mm.	--	---	---	---	---	---
Ischium length, mm.	--	---	---	---	---	---
Femur length, mm.	21	847.0	40.3	34287.00	0.54	1.3
Tibia length, mm.	21	855.0	40.7	34974.75	0.63	1.5
Fibula length, mm.	21	748.5	35.6	26787.25	0.51	1.4
Calcaneous length, mm.	21	352.0	16.8	5975.00	0.42	2.5
Metatarsal(3or4), mm.	21	356.5	17.0	6095.25	0.32	1.9
Metatarsal(2or5), mm.	21	234.0	11.1	2629.00	0.22	2.0
Liver weight, gm.	16	548.94	34.31	19872.51	2.08	8.1
Spleen weight, mg.	15	9507.	633.	7773985.	72.	11.4
L. Kidney weight, gm.	21	102399.	4876.	517986291.	211.	4.3
R. Kidney weight, gm.	21	99825.	4875.	496879537.	230.	4.7
L. Adrenal weight, mg.	20	2279.7	126.9	269639.73	5.1	4.0
R. Adrenal weight. mg.	20	2210.6	110.5	246688.96	2.5	2.2
L. Gonad weight, M., mg.	21	2973.2	141.6	----	---	---
L. Gonad weight, F., mg.	21	358.1	17.05	12077.31	---	---
R. Gonad weight, M., mg.	21	2863.5	136.3	----	---	---
R. Gonad weight, F., mg.	21	363.7	17.32	12438.17	---	---
Thyroid weight, mg.	21	1465.3	69.8	1395536.51	29.50	4.2
Heart weight, gm.	21	178.21	8.49	1583.30	0.41	4.8
Lung weight, gm.	21	423.04	20.14	9258.01	1.28	6.4
Brain weight, gm.	3	106.42	35.47	3788.31	1.50	4.2
Pituitary weight, mg.	20	517.0	25.8	13841.86	1.23	4.7

Appendix Table 3. Development of the fetal pig - measures at birth
(Combined data from Yorkshire gilts and 2nd-litter Duroc sows)

Measure	ΣX			ΣX^2		
	M	F	M & F	M	F	M & F
Body weight, gm.	33261.9	30559.0	63280.9	40447787.95	35390297.20	75838085.15
Crown-rump length, cm.	267.1	227.2	494.3	7968.97	6505.74	14475.71
Head width, cm.	80.43	77.93	158.36	407.08	382.84	789.93
Humerus H-C, cm.	84.03	80.99	165.02	442.69	412.24	854.93
Humerus T-C, cm.	87.77	85.93	173.70	484.95	464.23	949.98
Humerus length, mm.	611.5	607.5	1219.0	25155.25	24745.75	49901.00
Radius length, mm.	461.5	421.0	882.5	13399.75	11885.50	25285.25
Ulna length, mm.	611.0	572.5	1183.5	23510.00	21965.75	45475.75
Metacarpal(3or4), mm.	247.0	224.5	471.5	3859.00	3410.25	7269.25
Metacarpal(2or5), mm.	152.0	139.0	291.0	1466.50	1303.50	2770.00
Ilium length, mm.	167.0	108.0	275.0	4809.50	2966.00	7775.50
Ischium length, mm.	126.0	74.0	200.0	2719.50	1518.00	4237.50
Femur length, mm.	637.0	598.5	1235.5	25551.50	24007.75	49559.25
Tibia length, mm.	637.5	564.0	1201.5	25611.25	22481.50	48092.75
Fibula length, mm.	553.5	518.0	1071.5	19354.25	18024.00	37378.25
Calcaneous length, mm.	271.5	255.5	527.0	4679.75	4410.75	9090.50
Metatarsal(3or4), mm.	268.5	255.5	524.0	4553.25	4392.75	8946.00
Metatarsal(2or5), mm.	174.5	166.0	340.5	1930.25	1860.50	3790.75
Liver weight, gm.	432.12	363.87	795.99	14835.89	12396.75	27202.64
Spleen weight, mg.	15579.	11739.	27318.	19277041.	15003131.	34280172.
L. Kidney weight, gm.	72806.	66178.	138984.	350064390.	310873700.	660938090.
R. Kidney weight, gm.	73638.	62256.	135894.	359550330.	274778134.	634328469.
L. Adrenal weight, mg.	1907.2	1641.6	3548.8	235193.10	202318.26	437511.36
R. Adrenal weight, mg.	1804.2	1496.5	3300.7	211526.16	170810.75	382336.91
L. Gonad weight, mg.	4896.0	467.8	----	1646152.70	15179.76	----
R. Gonad weight, mg.	4627.1	479.7	----	1466039.01	15976.11	----
Thyroid weight, mg.	3601.1	3239.2	6840.4	880643.35	751686.73	1632330.08
Heart weight, gm.	132.36	114.89	247.25	1153.07	928.70	2081.77
Lung weight, gm.	320.08	273.89	593.97	6976.46	5424.78	12401.23
Brain weight, gm.	288.35	168.91	457.26	10418.35	5717.73	16136.07
Pituitary weight, mg.	426.2	370.3	796.5	12378.72	9504.96	21883.69

Appendix Table 3. (Continued)

Measure	N			X			S.E.			RSE
	M	F	M&F	M	F	M & F	M	F	M&F	M&F
Body weight, gm.	29	28	57	1146.96	1091.39	1139.66	53.2	51.9	37.1	3.5
Crown-rump length, cm.	9	8	17	29.67	28.40	29.07	.77	.98	.62	2.1
Head width, cm.	16	16	32	5.03	4.87	4.94	.11	.11	.08	1.6
Humerus H-C, ln., cm.	16	16	32	5.25	5.06	5.16	.07	.09	.07	1.3
Humerus T-C, ln., cm.	16	16	32	5.49	5.37	5.43	.17	.13	.08	1.4
Humerus length, mm.	16	15	31	40.76	40.50	40.63	1.0	.8	.6	1.5
Radius length, mm.	16	15	31	28.85	28.06	28.47	.6	.5	.4	1.4
Ulna length, mm.	16	15	31	38.18	38.16	38.18	.8	.7	.5	1.3
Metacarpal(3or4), mm.	16	15	31	15.43	14.96	15.20	.4	.5	.3	2.0
Metacarpal(2or5), mm.	16	15	31	9.50	9.26	9.38	.3	.3	.2	2.1
Ilium length, mm.	6	4	10	27.83	27.00	27.50	2.3	2.1	1.5	5.5
Ischium length, mm.	6	4	10	21.00	18.50	20.00	1.5	3.5	1.6	8.0
Femur length, mm.	16	15	31	39.81	39.90	39.85	.9	.8	.6	1.5
Tibia length, mm.	16	15	31	39.85	37.60	38.75	.9	2.7	1.3	3.4
Fibula length, mm.	16	15	31	34.59	34.53	34.56	.9	.8	.6	1.7
Calcaneous length, mm.	16	15	31	16.96	17.03	17.00	.5	.5	.4	2.4
Metatarsal (3or4), mm.	16	15	31	16.78	17.03	16.90	.4	.4	.3	1.8
Metatarsal (2or5), mm.	16	15	31	10.90	11.06	10.98	.3	.3	.1	0.9
Liver weight, gm.	14	12	26	30.69	30.32	30.62	2.34	3.21	2.09	6.8
Spleen weight, mg.	11	14	25	1112.	1067.	1092.7	103.	152.	86.	7.9
L.Kidney weight, gm.	16	15	31	4550.	4412.	4483.	280.	300.	201.	4.5
R. Kidney weight, gm.	16	15	31	4602.	4150.	4383.	283.	278.	207.	4.7
L. Adrenal weight, mg.	16	14	30	119.20	117.25	118.29	5.7	7.4	4.4	3.7
R. Adrenal weight, mg.	16	14	30	112.76	106.89	110.02	5.8	7.7	4.5	4.1
L. Gonad weight, mg.	16	15	31	306.00	31.18	----	24.7	1.7	---	---
R. Gonad weight, mg.	16	15	31	289.19	31.98	----	23.0	1.8	---	---
Thyroid weight, mg.	16	15	31	225.06	215.95	220.66	13.3	15.7	11.5	5.2
Heart weight, gm.	16	15	31	8.27	7.66	7.97	.49	.48	.34	4.3
Lung weight, gm.	16	15	31	20.01	18.26	19.16	1.53	1.42	1.04	5.4
Brain weight, gm.	8	5	13	36.04	33.78	35.17	.66	.75	.58	1.6
Pituitary weight, mg.	15	15	30	28.41	24.68	26.56	1.2	1.3	.9	3.3

Appendix Table 4. Development of the fetal pig - 93 days
(Data from first-litter Yorkshire gilts)

Measure	ΣX			ΣX^2		
	M	F	M&F	M	F	M&F
Body weight, gm.	11836.5	19625.1	31461.6	7599699.75	12353512.41	19951212.16
Crown-rump length, cm.	437.3	728.5	1165.80	10122.97	16624.93	26747.90
Head width, cm.	80.37	132.37	212.74	340.78	548.59	889.37
Humerus H-C, ln., cm.	65.89	100.84	166.73	257.18	392.63	649.81
Humerus T-C, ln., cm.	70.38	107.75	178.13	293.52	448.22	741.74
Humerus length, mm.	433.5	705.5	1139.0	2642.75	20850.25	33493.00
Radius length, mm.	297.0	479.0	776.0	5928.50	9603.50	15532.00
Ulna length, mm.	386.0	628.0	1014.0	10021.50	16507.50	26529.00
Metacarpal (3or4), mm.	143.5	232.0	375.5	1388.75	2256.50	3645.25
Metacarpal (2or5), mm.	185.5	138.0	223.5	492.25	802.00	1294.25
Ilium length, mm.	307.5	507.5	815.0	6361.25	10807.25	17168.50
Ischium length, mm.	227.0	366.0	593.0	3470.00	5619.50	9089.50
Femur length, mm.	418.0	688.5	1106.5	11782.50	19839.25	31621.75
Tibia length, mm.	398.2	655.0	1053.2	10690.54	17948.00	28638.54
Fibula length, mm.	341.5	546.0	887.5	7864.75	12533.25	20398.00
Calcaneous length, mm.	163.0	261.0	424.0	1796.50	2858.00	4654.50
Metatarsal (3or4), mm.	160.0	254.0	414.0	1727.00	2701.50	4428.50
Metatarsal (2or5), mm.	104.5	165.5	270.0	733.75	1150.75	1884.50
Liver weight, gm.	255.00	439.65	694.65	3703.79	6745.21	10449.00
Spleen weight, mg.	15295.	25512.	4080.70	14836861.	22434644.	37271505.
L. Kidney weight, gm.	38926.	62940.	101866.0	91071884.	162315596.	253387480.
R. Kidney weight, gm.	----	----	99196.0	----	----	-240328768.
L. Adrenal weight, mg.	633.4	1030.1	1663.5	26145.82	45595.49	71741.31
R. Adrenal weight, mg.	544.9	990.8	1535.7	22250.41	41014.64	63265.05
L. Gonad weight, mg.	1372.5	1083.5	---	130433.65	56205.13	----
R. Gonad weight, mg.	**1268.4**	**1058.2**	**---**	**120750.22**	**53619.54**	**----**
Thyroid weight, mg.	**1165.4**	**1879.6**	**3045.0**	**1460141.48**	**255366.86**	**601408.36**
Heart weight, gm.	**69.14**	**105.87**	**175.01**	**288.67**	**446.98**	**734.64**
Lung weight, gm.	**263.64**	**428.81**	**692.45**	**4671.99**	**7696.45**	**12368.44**
Brain weight, gm.	**346.36**	**590.60**	**936.96**	**7982.48**	**13923.76**	**21906.24**
Pituitary weight, mg.	**157.5**	**258.8**	**416.3**	**2997.73**	**5336.40**	**8334.13**

Appendix Table 4. (Continued)

Measure	N			X			S.E.			RSE
	M	F	M&F	M	F	M & F	M	F	M&F	M&F
Body weight, gm.	19	32	51	622.97	613.28	616.89	16.0	17.9	15.0	2.4
Crown-rump length, cm.	19	32	51	23.01	22.76	22.86	0.4	0.2	0.2	0.9
Head width, cm.	19	32	51	4.23	4.14	4.17	0.05	0.03	0.03	0.7
Humerus H-C, ln., cm.	17	26	43	3.88	3.88	3.88	0.08	0.05	0.01	0.3
Humerus T-C, ln., cm.	17	26	43	4.14	4.14	4.14	0.09	0.05	0.05	1.2
Humerus length, mm.	15	24	39	28.90	29.39	29.20	0.7	0.4	0.4	1.4
Radius length, mm.	15	24	39	19.80	19.95	19.90	0.5	0.3	0.2	2.0
Ulna length, mm.	15	24	39	25.73	26.16	26.00	0.6	0.4	0.3	1.2
Metacarpal (3or4), mm.	15	24	39	9.56	9.66	9.60	0.3	0.2	0.1	1.0
Metacarpal (2or5), mm.	15	24	39	5.70	5.75	5.70	0.2	0.1	0.1	1.7
Ilium length, mm.	15	24	39	20.50	21.14	20.90	0.5	0.4	0.3	1.4
Ischium length, mm.	15	24	39	15.13	15.25	15.20	0.4	0.3	0.2	1.3
Femur length, mm.	15	24	39	27.86	28.68	28.40	0.8	0.4	0.4	1.4
Tibia length, mm.	15	24	39	26.54	27.29	27.00	0.8	0.4	0.4	1.5
Fibula length, mm.	15	24	39	22.76	22.77	22.76	0.7	0.4	0.4	1.7
Calcaneous length, mm.	15	24	39	10.86	10.87	10.87	0.3	0.2	0.4	3.6
Metatarsal (3or4), mm.	15	24	39	10.66	10.58	10.60	0.3	0.2	0.2	1.9
Metatarsal (2or5), mm.	15	24	39	6.96	6.89	6.92	0.2	0.1	0.1	1.4
Liver weight, gm.	18	31	49	14.17	14.18	14.18	0.55	0.74	0.51	3.6
Spleen weight, mg.	18	31	49	850.	823.	832.79	78.	39.	37.	4.4
L. Kidney weight, gm.	17	26	43	2290.	2251.	2368.97	84.	124.	82.	3.5
R. Kidney weight, gm.	--	--	43	----	----	2306.88	---	---	80.	3.5
L. Adrenal weight, mg.	16	25	41	39.58	41.20	40.57	2.1	2.3	1.6	3.8
R. Adrenal weight, mg.	14	26	40	38.92	38.10	38.39	2.4	2.2	1.7	3.6
L. Gonad weight, mg.	16	25	41	85.78	43.34	---	7.3	3.9	---	---
R. Gonad weight, mg.	15	25	40	84.56	42.32	---	8.0	3.8	---	---
Thyroid weight, mg.	10	14	24	116.54	134.25	126.88	1.1	4.1	5.2	4.1
Heart weight, gm.	17	26	43	4.07	4.07	4.07	0.17	0.16	0.11	2.9
Lung weight, gm.	16	25	41	16.48	17.15	16.89	1.17	0.75	0.65	3.8
Brain weight, gm.	16	26	42	21.6	22.70	22.3	1.42	0.88	0.76	3.4
Pituitary weight, mg.	9	13	22	17.50	19.90	18.9	1.8	1.1	0.3	1.6

Appendix Table 5. Development of fetal pigs - 72 days
(Data from first-litter Yorkshire gilts)

Measure	ΣX			ΣX²		
	M	F	M & F	M	F	M & F
Body weight, gm.	5997.0	4875.5	11384.5	1430387.00	1066577.75	2496964.75
Crown-rump length, cm.	429.7	370.3	800.0	7143.49	6005.09	13148.58
Head width, cm.	83.03	71.45	154.48	266.33	223.85	490.18
Humerus H-C, ln., cm.	61.68	50.53	112.21	152.56	122.23	274.80
Humerus T-C, ln., cm.	66.97	54.26	121.23	179.89	140.93	320.83
Humerus length, mm.	419.5	340.0	759.5	7064.75	5555.50	12620.25
Radius length, mm.	307.5	251.0	558.5	3794.25	3030.00	6824.25
Ulna length, mm.	375.5	307.0	682.5	5667.25	4530.00	10197.25
Metacarpal (3or4), mm.	129.5	105.5	235.0	678.75	536.75	1215.50
Metacarpal (2or5), mm.	87.0	77.5	164.5	308.00	312.25	620.25
Ilium length, mm.	320.5	261.0	581.5	4144.25	3278.50	7422.75
Ischium length, mm.	216.0	174.5	390.5	1880.00	1473.25	3353.25
Femur length, mm.	402.5	328.5	731.0	6516.75	5172.00	11688.75
Tibia length, mm.	387.0	310.0	697.0	6021.50	4634.00	10655.5
Fibula length, mm.	337.5	253.5	591.0	4581.25	3255.75	7837.00
Calcaneous length, mm.	130.5	99.5	230.0	694.75	484.75	1179.50
Metatarsal (3or4), mm.	140.0	113.5	253.5	792.50	622.75	1415.25
Metatarsal (2or5), mm.	96.5	76.0	172.5	375.25	283.50	658.75
Liver weight, gm.	170.60	125.75	296.35	1230.33	834.45	2064.79
Spleen weight, mg.	5486.	3718.	9204.	1305688.	720762.	2026450.
L. Kidney weight, gm.	28827.	21460.	50287,	34396369.	23890860.	58287229.
R. Kidney weight, gm.	28138.	20580.	48718.	32782364.	21896174.	54678538.
L. Adrenal weight, mg.	652.6	462.2	1114.80	17709.06	10766.28	28475.34
R. Adrenal weight, mg.	526.5	376.3	902.8	12300.51	7372.01	19672.52
L. Gonad weight, mg.	830.7	424.7	----	31172.53	9516.59	----
R. Gonad weight, mg.	830.0	395.3	----	29072.82	8087.29	----
Thyroid weight, mg.	1467.4	1146.3	2613.7	89374.46	67148.49	156522.95
Heart weight, gm.	40.87	31.07	71.94	69.37	49.55	118.92
Lung weight, gm.	158.48	117.29	275.77	1052.48	703.40	1755.87
Brain weight, gm.	233.87	191.80	425.67	2202.23	1767.07	3969.31
Pituitary weight, mg.	192.2	145.1	337.3	2001.64	1299.89	3301.53

Appendix Table 5. (Continued)

Measure	N			$\bar{X}$			S.E.			RSE
	M	F	M&F	M	F	M&F	M	F	M&F	M&F
Body weight, gm.	26	23	49	230.65	208.33	220.54	11.1	25.6	7.3	3.0
Crown-rump length, cm.	26	23	49	16.52	16.10	16.33	0.3	0.3	0.2	1.2
Head width, cm.	26	23	49	3.19	3.11	3.15	0.04	0.06	0.03	0.9
Humerus H-C, ln., cm.	25	21	46	2.47	2.41	2.44	0.03	0.04	0.02	0.8
Humerus T-C, ln., cm.	25	21	46	2.68	2.58	2.64	0.03	0.04	0.03	0.1
Humerus length, mm.	25	21	46	16.78	16.19	16.51	0.2	0.3	0.2	1.2
Radius length, mm.	25	21	46	12.30	11.95	12.14	0.1	0.3	0.1	0.8
Ulna length, mm	25	21	46	15.02	14.61	14.84	0.2	0.3	0.2	1.3
Metacarpal (3or4), mm.	25	21	46	5.18	5.02	5.10	0.1	0.1	0.1	--
Metacarpal (2or5), mm.	25	21	46	3.48	3.69	3.58	0.0	0.2	0.1	--
Ilium length, mm.	25	21	46	12.82	12.42	12.64	0.2	0.3	0.2	--
Ischium length, mm.	25	21	46	8.64	8.30	8.49	0.1	0.2	0.1	--
Femur length, mm.	25	21	46	16.10	15.61	15.89	0.2	0.3	0.2	1.3
Tibia length, mm.	25	21	46	15.48	14.76	15.15	0.2	0.4	0.2	1.3
Fibula length, mm.	25	20	45	13.50	12.67	13.13	0.2	0.3	0.2	1.5
Calcaneous length, mm.	25	21	46	5.22	4.73	5.00	0.1	0.2	0.1	--
Metatarsal (3or4), mm.	25	21	46	5.60	5.40	5.51	0.1	0.1	0.1	--
Metatarsal (2or5), mm.	25	21	46	3.86	3.61	3.75	0.0	0.1	0.1	--
Liver weight, gm.	25	21	46	6.82	5.99	6.44	0.11	0.44	0.23	3.6
Spleen weight, mg.	25	21	46	219.48	277.05	200.09	13.	12.	9.	4.5
L. Kidney weight, gm.	25	21	46	1153.	1022.	1093.	44.	69.	33.	3.0
R. Kidney weight, gm.	25	21	46	1125.	980.	1059.	43.	64.	39.	3.7
L. Adrenal weight, mg.	25	21	46	26.10	22.00	24.23	1.1	1.2	0.8	3.3
R. Adrenal weight, mg.	24	20	44	21.93	18.81	20.50	1.2	0.9	0.8	4.0
L. Gonad weight, mg.	25	21	46	34.42	20.22	---	1.6	1.5	--	--
R. Gonad weight, mg.	25	21	46	33.20	18.82	---	1.6	1.2	--	--
Thyroid weight, mg.	25	21	46	58.69	54.58	56.82	2.3	3.3	2.0	3.5
Heart weight, gm.	25	21	46	1.63	1.48	1.56	0.07	0.09	0.05	3.2
Lung weight, gm.	25	21	46	6.34	5.59	6.00	0.28	0.34	0.22	3.7
Brain weight, gm.	25	21	46	9.35	9.13	9.25	0.16	0.19	0.12	1.3
Pituitary weight, mg.	20	17	37	9.61	8.53	9.12	0.6	0.5	0.4	4.4

Appendix Table 6. Development of the fetal pig - 51 days
(Data from first-litter Yorkshire gilts)

Measure	ΣX			ΣX^2		
	M	F	M & F	M	F	M & F
Body weight, gm.	1310.7	1281.5	2592.20	71046.19	62982.25	134028.44
Crown-rump length, cm.	248.5	262.5	511.0	2483.85	2564.23	5048.08
Head width, cm.	48.28	51.18	99.46	93.48	97.30	190.79
Humerus H-C, ln, cm.	24.00	33.52	57.52	34.00	47.00	81.01
Humerus T-C, ln, cm.	26.33	36.35	52.68	41.01	55.44	96.44
Humerus length, mm.	142.5	174.5	317.0	1141.75	1342.25	2484.00
Radius length, mm.	102.0	128.5	230.5	585.00	728.25	1313.25
Ulna length, mm.	110.0	150.0	260.0	722.00	991.00	1713.00
Metacarpal (3or4), mm.	32.5	41.0	73.5	61.25	76.50	137.75
Metacarpal (2or5), mm.	8.0	10.5	18.5	9.50	11.75	21.25
Ilium length, mm.	96.0	116.0	212.0	526.0	625.50	1151.50
Ischium length, mm.	30.0	37.0	67.0	79.00	94.00	173.00
Femur length, mm.	123.0	156.0	279.0	855.50	1080.50	1936.00
Tibia length, mm.	114.0	147.0	261.0	736.50	953.50	1690.00
Fibula length, mm.	10.0	10.0	20.0	52.00	52.00	104.00
Calcaneous length, mm.	---	---	---	---	---	---
Metatarsal (3or4), mm.	26.5	36.0	62.5	45.75	63.50	109.25
Metatarsal (2or5), mm.	---	---	---	---	---	---
Liver weight, gm.	66.08	77.66	143.74	227.82	263.75	491.58
Spleen weight, mg.	15579.	11739.	27318.0	1927704l.	15003131.	36188038.
L. Kidney weight, gm.	5303.	7623.	12926.	1934547.	3024709.	5059356.
R. Kidney weight, gm.	5971.	5976.	13947.	2299303.	3168902.	5468205.
L. Adrenal weight, mg.	152.6	181.7	334.3	1614.92	1912.99	3527.91
R. Adrenal weight, mg.	126.3	196.6	322.9	1261.91	2018.36	3280.27
L. Gonad weight, mg.	191.9	200.3	---	2535.97	2077.55	---
R. Gonad weight, mg.	162.1	187.1	---	2153.65	1848.95	---
Thyroid weight, mg.	149.9	207.0	356.9	1541.15	2179.42	3720.57
Heart weight, gm.	6.89	9.13	16.02	3.09	3.93	7.02
Lung weight, gm.	20.74	25.73	46.47	28.63	32.49	60.12
Brain weight, gm.	32.56	42.83	75.39	68.38	85.94	154.32
Pituitary weight, mg.	10.2	9.4	19.6	35.24	23.40	58.64

Appendix Table 6. (Continued)

Measure	N			$\bar{X}$			S.E.			RSE
	M	F	M&F	M	F	M&F	M	F	M&F	M&F
Body weight, gm.	25	27	52	52.42	47.46	49.85	1.9	1.7	1.4	2.8
Crown-rump length, cm.	25	27	52	9.86	9.72	9.83	.1	.1	.1	1.3
Head width, cm.	25	27	52	1.93	1.90	1.91	.02	.02	.01	.5
Humerus H-C, ln., cm.	17	24	41	1.41	1.40	1.40	.02	.02	.01	.7
Humerus T-C. ln., cm.	17	24	41	1.55	1.51	1.53	.03	.02	.02	1.3
Humerus length, mm.	18	23	41	7.91	7.58	7.73	.2	.2	.1	1.3
Radius length, mm.	18	23	41	5.66	5.58	5.62	.1	.1	.1	1.8
Ulna length, mm.	17	23	40	6.47	6.52	6.50	.2	.1	.1	1.5
Metacarpal (3or4), mm.	18	23	41	1.80	1.78	1.79	.1	.1	.1	--
Metacarpal (2or5), mm.	7	10	17	1.14	1.05	1.09	.1	.1	.1	--
Ilium length, mm.	18	22	40	5.33	5.27	5.30	.2	.1	.1	--
Ischium length, mm.	12	15	27	2.50	2.46	2.48	.2	.1	.1	--
Femur length, mm.	18	23	41	6.83	6.78	6.80	.2	.2	.1	1.4
Tibia length, mm.	18	23	41	6.33	6.39	6.37	.2	.1	.1	1.6
Fibula length, mm.	2	2	4	5.00	5.00	5.00	1.0	1.0	0.6	12.0
Calcaneous length, mm.	-	-	-	--	--	--	--	--	--	--
Metatarsal (3or4), mm.	17	22	39	1.55	1.63	1.60	.1	.1	.1	--
Metatarsal (2or5), mm.	-	-	-	--	--	--	--	--	--	--
Liver weight, gm.	20	24	44	3.30	3.24	3.25	.16	.15	.10	3.2
Spleen weight, mg.	20	24	44	1112.	1067.	1092.	103.	150.	103.	9.7
L. Kidney weight, gm.	15	21	36	353.	363.	359.	17.	25.	18.	5.0
R. Kidney weight, gm.	16	22	38	373.	363.	367.	17.	24.	16.	4.0
L. Adrenal weight, mg.	16	20	36	9.53	9.08	9.28	.8	.8	.6	--
R. Adrenal weight, mg.	14	21	35	9.02	9.36	9.23	.8	.6	.5	--
L. Gonad weight, mg.	15	20	35	12.79	10.01	---	.6	.4	--	--
R. Gonad weight, mg.	13	20	33	12.46	9.35	---	.9	.5	--	--
Thyroid weight, mg.	15	21	36	9.99	9.85	9.91	.5	.6	.4	4.0
Heart weight, gm.	16	22	38	.43	.42	.42	.02	.01	.01	2.4
Lung weight, gm.	16	22	38	1.30	1.17	1.22	.08	.07	.05	4.0
Brain weight, gm.	16	22	38	2.04	1.95	1.98	.09	.07	.06	3.0
Pituitary weight, mg.	3	4	7	3.40	2.34	2.80	.3	.3	.3	10.1

Appendix Table 7. Development of the fetal pig - 45 days
(Data from crossbred first-litter gilts)

Measure	ΣX			ΣX^2		
	M	F	M&F	M	F	M&F
Body weight, gm.	855.4	557.4	1412.80	40370.30	20113.32	60483.62
Crown-rump length, cm.	172.9	121.8	294.7	1537.85	941.38	2479.23
Head width, cm.	35.29	28.98	64.27	57.87	43.03	100.90
Humerus H-C, length, cm.	29.10	23.49	52.59	39.43	28.36	67.79
Humerus T-C, length, cm.	30.08	24.03	54.11	44.05	31.23	75.28
Humerus length, mm.	128.1	90.0	218.1	890.50	517.50	1408.0
Radius length, mm.	86.5	65.0	151.5	425.75	300.00	725.75
Ulna length, mm.	110.0	71.5	181.5	674.00	375.75	1015.75
Metacarpal (3or4), mm.	25.0	14.0	39.0	41.00	23.50	64.5
Metacarpal (2or5), mm.	5.0	1.0	6.0	17.00	1.00	18.00
Ilium length, mm.	71.5	46.0	117.5	363.75	190.00	553.75
Ischium length, mm.	5.5	4.0	9.5	15.25	8.00	23.25
Femur length, mm.	115.5	73.5	189.0	714.75	386.25	1101.0
Tibia length, mm.	91.0	44.5	135.5	588.50	273.25	984.0
Fibula length, mm.	5.5	9.5	15.0	30.25	16.75	47.00

Appendix Table 7. (Continued)

Measure	N			$\bar{X}$			S.E.			RSE
	M	F	M&F	M	F	M&F	M	F	M&F	M&F
Body weight, gm.	22	20	44	38.88	27.87	33.50	3.9	3.5	2.8	8.7
Crown-rump length, cm.	20	16	36	8.64	7.61	8.19	0.3	0.2	0.2	2.4
Head width, cm.	22	20	42	1.60	1.45	1.53	0.05	0.05	0.04	2.6
Humerus H-C, ln., cm.	22	20	42	1.37	1.17	1.25	0.04	0.05	0.04	3.2
Humerus T-C. ln., cm.	21	19	40	1.43	1.26	1.28	0.05	0.05	0.04	3.1
Humerus length, mm.	21	19	40	6.09	4.73	5.45	0.5	0.5	0.4	7.3
Radius length, mm.	20	17	37	4.32	3.82	4.09	0.4	0.4	0.3	7.3
Ulna length, mm.	20	16	36	5.50	4.46	5.04	0.4	0.5	0.3	5.9
Metacarpal (3or4), mm.	17	10	27	1.47	1.40	1.44	0.1	0.2	0.1	--
Metacarpal (2or5), mm.	2	1	3	2.50	1.00	2.00	0.5	--	1.0	--
Ilium length, mm.	15	12	27	4.76	3.83	4.35	0.3	0.3	0.2	--
Ischium length, mm.	2	2	4	2.75	2.00	2.38	0.2	--	0.2	--
Femur length, mm.	21	18	39	5.50	4.08	4.85	0.4	0.5	0.4	8.25
Tibia length, mm.	15	8	23	6.06	5.56	5.89	0.4	0.7	0.6	10.19
Fibula length, mm.	1	7	8	1.23	1.35	1.29	0.2	0.3	0.1	--

Appendix Table 8. Development of the fetal pig - 30 days
(Data from first-litter Yorkshire gilts

Measure	ΣX M&F	ΣX^2 M&F	N	$\bar{X}$ M&F	S.E.	RSE
Body weight, gm.	40.6	63.10	27	1.50	.05	3.3
Crown-rump length, cm.	62.3	155.81	25	2.49	.03	1.2
Head width, cm.	16.88	11.64	25	.68	.02	2.9

Appendix Table 9. Enzyme analysis - birth

A. Alkaline phosphatase
mM of p-nitrophenol per 30 min. per 0.01 mg. of wet tissue.

	N	ΣX	ΣX^2	$\bar{X}$	SE
1. Duodenum, cranial	10	.74	0.1334	0.07	0.03
2. Duodenum, caudal	8	1.21	0.2281	0.15	0.03
3. J. I., cranial	12	3.05	0.8617	0.25	0.03
4. J. I., middle	12	3.65	1.2547	0.30	0.03
5. J. I., caudal	11	1.10	0.1470	0.10	0.02
Total	53	9.75	2.6249	0.18	0.02

F = 13.42**; SEE = 0.02; number 3 and number 4 are significantly different from all others, but not from each other.

B. Acid phosphatase
mM of p-nitrophenol per 30 min. per 0.16 mg. of wet tissue.

	N	ΣX	ΣX^2	$\bar{X}$	SE
1. Duodenum, cranial	10	1.60	0.2668	0.16	0.01
2. Duodenum, caudal	8	1.76	0.4708	0.22	0.04
3. J. I., cranial	12	3.21	0.8781	0.27	0.01
4. J. I., middle	12	3.12	0.8556	0.26	0.02
5. J. I., caudal	11	2.85	0.8077	0.26	0.03
Total	53	12.54	3.2790	0.23	0.02

F = 4.44**; SEE = 0.02; number 1 is significantly different from numbers 3, 4 and 5 but not from number 2.

C. Lactase
mM of o-nitrophenol per 15 min. per 100 mg. of wet tissue.

	N	ΣX	ΣX^2	$\bar{X}$	SE
1. Duodenum, cranial	10	0.327	0.011205	0.033	0.002
2. Duodenum, caudal	7	0.462	0.034834	0.066	0.010
3. J. I., cranial	12	0.748	0.047756	0.062	0.003
4. J. I., middle	11	0.687	0.043677	0.062	0.003
5. J. I., caudal	11	0.479	0.022159	0.044	0.002
Total	50	2.703	0.159631	0.054	0.004

F = 11.88**; See = 0.004; numbers 1 and 5 are significantly different from numbers 2, 3 and 4 but not each other.

Appendix Table 10. Enzyme analysis - 93 days

A. Alkaline phosphatase
mM of p-nitrophenol per 30 min. per 0.1 mg. of wet tissue.

	N	ΣX	ΣX^2	$\bar{X}$	SE
1&2. Duodenum[a]	4	0.42	0.0526	0.11	0.02
3. J. I., cranial	8	1.00	0.1356	0.13	0.02
4. J. I., middle	4	0.41	0.0509	0.10	0.03
5. J. I., caudal	7	0.82	0.1212	0.12	0.02
Total	23	2.65	0.3603	0.12	0.01

F = 0.21; SEE = 0.01.

B. Acid phosphatase
mM of p-nitrophenol per 30 min. per 0.16 mg. of wet tissue.

	N	ΣX	ΣX^2	$\bar{X}$	SE
1&2. Duodenum[a]	5	0.63	0.0851	0.13	0.02
3. J. I., cranial	9	1.35	0.2229	0.15	0.02
4. J. I., middle	5	0.66	0.0890	0.13	0.04
5. J. I., caudal	6	0.85	0.1241	0.14	0.01
Total	25	3.49	0.5211	0.14	0.01

F = 0.47; SEE = 0.01.

C. Lactase
mM of o-nitrophenol per 15 min. per 100 mg. of wet tissue.

	N	ΣX	ΣX^2	$\bar{X}$	SE
1&2. Duodenum[a]	6	0.177	0.006689	0.029	0.007
3. J. I., cranial	10	0.395	0.016753	0.040	0.004
4. J. I., middle	5	0.199	0.008413	0.040	0.016
5. J. I., caudal	6	0.209	0.007709	0.035	0.004
Total	27	0.980	0.039564	0.036	0.003

F = 23.07**; SEE = 0.003; number 1 and 2 are significantly different from numbers 3, 4 and 5.

[a] The data includes samples from the cranial and caudal portions of the duodenum.

Appendix Table 11. Enzyme analysis - 72 days

A. Alkaline phosphatase
mM of p-nitrophenol per 30 min. per mg. of wet tissue.

	N	ΣX	ΣX^2	$\bar{X}$	SE
1&2. Duodenum[a]	10	3.01	0.9823	0.30	0.03
3. J. I., cranial	7	2.62	1.2180	0.37	0.07
4. J. I., middle	6	2.86	1.6186	0.48	0.09
5. J. I., caudal	10	2.93	1.2079	0.29	0.06
Total	33	11.42	5.0268	0.34	0.05

F = 22.30**; SEE = 0.05; 1 and 2 are significantly different from 3 and 4, but not 5.

B. Acid phosphatase
mM of p-nitrophenol per 30 min. per 0.16 mg. of wet tissue.

	N	ΣX	ΣX^2	$\bar{X}$	SE
1&2. Duodenum[a]	13	1.45	0.1911	0.11	0.01
3. J. I., cranial	7	1.02	0.1504	0.15	0.01
4. J. I., middle	6	0.84	0.1212	0.14	0.01
5. J. I., caudal	10	0.90	0.0976	0.09	0.01
Total	36	4.21	0.5603	0.12	0.002

F = 34.56**; SEE = 0.002; 1 and 2 are significantly different from 3 and 4 but not 5.

C. Lactase
mM of o-nitrophenol per 15 min. per 100 mg. of wet tissue.

	N	ΣX	ΣX^2	$\bar{X}$	SE
1&2. Duodenum[a]	12	0.189	0.003729	.016	.002
3. J. I., cranial	7	0.154	0.003388	.022	.002
4. J. I., middle	5	0.100	0.002234	.020	.003
5. J. I., caudal	11	0.091	0.002036	.008	.003
Total	35	0.534	0.011593	.015	.002

F = 3.975: SEE = 0.002.

[a] The data includes samples from the cranial and caudal portions of the duodenum.

Appendix Table 12. Enzyme analysis - 51 days and 30 days

A. Alkaline phosphatase
mM of p-nitrophenol per 30 min. per mg. of wet tissue.

	N	ΣX	ΣX^2	$\bar{X}$	SE
51 days[a]	7	2.59	1.2269	0.37	0.08
30 days[b]	3	1.90	1.3578	0.63	0.16

B. Acid phosphatase
mM of p-nitrophenol per 30 min. per 0.16 mg. of wet tissue.

	N	ΣX	ΣX^2	$\bar{X}$	SE
51 days[a]	7	1.04	0.1626	0.15	0.01
30 days[b]	3	0.38	0.0490	0.13	0.01

C. Lactase
mM of o-nitrophenol per 15 min. per 100 mg. of wet tissue.

	N	ΣX	ΣX^2	$\bar{X}$	SE
51 days[a]	6	.167	.005601	0.028	.002
30 days[b]	3	.044	.000596	0.016	.002

[a] The data includes all samples of the small intestine regardless of location.

[b] The data are from pooled samples of 8 fetuses.

Appendix Table 13. Percent dry matter of fetal intestinal tissue

Period	Percent
30 days	13.4 (estimated)
51 days	13.4 (duplicate analysis)
72 days	13.8 ∓0.1
93 days	14.5 ∓0.5
Birth	17.2 ∓0.7

[a] These percentage were used to convert assays to dry matter basis.