FACTORS AFFECTING BIRTH WEIGHTS OF SWINE¹

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Received July 6, 1933

INTRODUCTION

The large variability in birth weights of mammals, particularly of multiparous mammals, suggests that many factors or conditions may be responsible for these differences. The present paper presents estimates of the relative importance of some of those things which cause the birth weights of swine to vary.

MATERIAL AND METHODS

The data were taken from the breeding and farrowing records of the Animal Husbandry Section of the IOWA AGRICULTURAL EXPERIMENT STATION during the years 1915 and 1917 to 1930 inclusive. The data were collected in connection with other experiments² not planned expressly to make this study possible. Yet no practice was followed which seems likely to have affected the birth weights in a way which would have invalidated this analysis.

The data analyzed are the birth weights of 506 litters containing 3639 pigs, all of which were produced by gilts about one year old at the time of farrowing. The time of weighing ranged from immediately after birth in some cases to a little more than twelve hours after birth in a few cases. Some pigs had suckled before being weighed but others had not. All litters were farrowed in the months of April and May, except nine in June, one in July and three in August. The breeds included purebred or high grade Poland Chinas, Tamworths, Hampshires and six different crosses. Over 71 percent of all these litters were purebred or high grade Poland Chinas.

To determine the importance of each factor affecting birth weight, FISHER'S (1930) method of analyzing variance was used. The percentage of the variance which disappears when a certain variable is held constant may be used to express the closeness of the relation between that variable and birth weight (table 3). For those accustomed to think in terms of correlation coefficients, it is easy to understand such a proportion as equivalent to a squared primary correlation coefficient between birth weight

¹ Journal Paper No. J 116 of the IOWA AGRICULTURAL EXPERIMENT STATION, Ames, Iowa.

² Dr. JOHN M. EVVARD and Professor C. C. CULBERTSON were in charge of this work and at different times the immediate responsibility for collecting these data rested on C. C. CULBERTSON, RUSSELL DUNN, C. F. BASSETT and W. E. HAMMOND.

and the variable which is held constant, provided the relations are rectilinear. In this study, the uneven distribution of the variables from year to year makes it impossible to separate the entire variance in birth weight completely into independent components ascribable to each of the variables or causes. When each of the variables in turn is studied, taking out the effects of only one or two at a time, approximate estimates are obtained of the importance of each variable as a cause or indicator of variance in birth weight, but each such estimate includes some of the variance which is jointly caused by the variable being considered and by other variables correlated with that one (table 4).

Because pigs born dead may have died an uncertain number of days before birth, it seemed best to analyze separately the data for all pigs farrowed and the data for only those pigs born alive.

FINDINGS

Sex ratio

Although not essentially related to the scope of this report, a discussion of the frequency of the different sex combinations seems of sufficient interest to be included here. MCPHEE (1927) reported for 17290 pigs from several experimental herds, a sex ratio of 52.0 percent males. He found also that herdbook data from the Chester White Record and from the Duroc Jersey Record showed significant departures from the expected frequencies of the different sex combinations. Data collected from the experimental herds of the UNITED STATES DEPARTMENT OF AGRICULTURE however were in agreement with the expected values obtained by expanding the binomial $(p+q)^n$.

In the population of 3639 pigs of the IOWA STATION the sex ratio is $51.1 \pm .6$ percent males. The probabilities that the distributions of sex combinations are random in each litter size for litters of 4-10 pigs are .29, .21, .31, .09, .08, .08, and .67 respectively. These values for P are still within what are usually considered the limits of significant departures from expectation. When these seven probabilities are combined by adding the χ^2 obtained for each litter size, the resulting probability that the distribution of sex combinations through all these litter sizes is random becomes almost exactly .05. However such departures from expectation as do exist, show no consistent excess or deficiency of litters which are predominantly of one sex. For example in the 9-pig litters the principal deficit is in litters containing 3 males while the principal excess is in litters containing 4 males. Hence it is concluded that the frequency of sex combinations was probably a chance affair conforming to the binomial $(p+q)^n$ in which $p = .511$.

The χ^2 test shows a probability of .72 that the differences observed in the mean sex ratio from litter size to litter size (for litters of 4-10 pigs inclusive) could have resulted from errors of random sampling. This indicates (as is to be expected from the mechanism of sex determination) that the sex ratio is not affected by litter size. HAINES (1931) found this true of guinea pigs also.

FIGURE 1.—Frequency distribution of birth weights of swine in these Iowa data.

TABLE 1
Mean birth weights of pigs.

	NUMBER OF PIGS	RANGE (LBS.)	MEAN BIRTH WEIGHT (LBS.)	STANDARD DEVIATION
All pigs	3639	0.8-4.5	2.69	.55
Live males	1755	1.0-4.5	2.78	.54
Live females	1672	1.2-4.3	2.66	.51
Dead males	106	0.8-4.0	2.31	.71
Dead females	106	1.0-3.8	2.11	.80

Effects of sex on birth weight

Data collected by CARMICHAEL and RICE (1926) for 5188 pigs show birth weights ranging from 0.2 pounds to 4.9 pounds, males generally being heavier than females. Similar observations were made by MCKENZIE (1928) and by KUHLMAN (unpublished).

The distribution of the number of pigs in each weight class in this study is shown in figure 1. The bimodality in the curves does not seem to have any biological basis. It is more likely to have resulted from the observers having an unconscious psychological bias in favor of even pounds and half pounds when weighing the pigs. The plan was to weigh the pigs accurately to the nearest tenth of a pound, but the classes including whole and half pound weights show excesses as compared with the neighboring classes. Table 1 shows the important data about birth weights according to sex and according to whether they were alive or dead at the time of birth. Males are slightly but significantly heavier than the females. Pigs born alive are heavier than pigs born dead. Pigs born dead vary more in weight than live pigs do. The analysis of variance shows that the sex difference is highly significant (P is far less than .01) yet the variance among pigs of the same sex is only 1.3 percent less than the variance in the total population of 3639 pigs. Among the pigs born alive, eliminating the sex difference reduces the variance 1.1 percent. The conclusion seems inescapable that the sex difference in birth weight is real but comparatively unimportant among the other causes of differences in birth weight. HAINES (1931) also found the sex difference in the birth weights of guinea pigs slight and was not quite certain of its significance. However he found males rather consistently heavier than females, just as we do here.

When the difference between the mean weights of those pigs born dead and those born alive is removed, the remaining variance is 4.8 percent less than the original variance, thus showing that for birth weights the difference between alive and dead is more important than the difference between male and female. It is likely that some of those born dead may have died several days before birth. Their smaller and more variable weight therefore partly results from variation in their stage of development at the time of death, as well as from whatever conditions caused their death.

Litter size and birth weight

The average birth weights for the different litter sizes are shown in table 2 and figure 2. The mean litter size for the 506 Iowa litters (all out of gilts) is $7.19 \pm .07$ pigs per litter. The birth weights reported by CARMICHAEL and RICE (1926), MCKENZIE (1928) and KUHLMAN (unpublished) are given for comparison. As a whole, the Iowa data are similar to the other data. The heavier pigs are farrowed in the smaller litters although the relation seems not to be quite rectilinear. In all four sets of data, pigs in litters of 1 or 2 are not quite as heavy as those in litters of about 3 to 5 pigs. Apparently the conditions which lead to the conception of exceedingly small litters are not the optimum for developing large pigs among

TABLE 2
Relation between average birth weight and litter size.

IOWA STATION			CARMICHAEL AND RICE		MCKENZIE		KUHLMAN		MULTIPLY ACTUAL BIRTH WEIGHTS BY THE FOLLOWING FACTORS TO CORRECT TO A STANDARD LITTER SIZE OF NINE PIGS
NUMBER IN LITTER	NUMBER OF LITTERS	MEAN BIRTH WEIGHT (LBS.)	NUMBER OF LITTERS	MEAN BIRTH WEIGHT (LBS.)	NUMBER OF LITTERS	MEAN BIRTH WEIGHT (LBS.)	NUMBER OF LITTERS	MEAN BIRTH WEIGHT (LBS.)	
1	4	2.15	5	2.46	..	..	2	2.50	1.07
2	8	2.89	14	2.79	1	2.19	..	..	.94
3	19	2.81	19	2.82	14	2.68	4	2.67	.91
4	31	3.19	40	2.75	14	2.40	8	2.97	.90
5	57	2.87	54	2.80	8	2.67	14	2.61	.92
6	65	2.77	62	2.62	28	2.41	19	2.60	.94
7	89	2.74	80	2.65	23	2.27	32	2.60	.96
8	73	2.73	83	2.62	31	2.32	27	2.67	.98
9	81	2.60	69	2.46	36	2.41	36	2.50	1.00
10	52	2.54	81	2.53	29	2.23	35	2.53	1.02
11	18	2.53	54	2.47	29	2.35	33	2.34	1.03
12	8	2.50	39	2.45	13	2.05	19	2.47	1.05
13	1	2.13	22	2.41	7	2.28	11	2.12	1.06
14	..	..	15	2.41	7	2.34	6	2.15	1.08
15	..	..	4	2.51	1	2.98	6	2.53	1.09
16	..	..	2	2.40	..	..	4	1.91	1.10
17	..	..	..	..	1	2.26	..	..	1.11
18	..	..	1	2.38	..	..	..	..	1.12
20	..	..	1	2.51	..	..	..	..	1.12
Total	506	2.69	645	2.55	242	2.33	256	2.47

FIGURE 2.—Average birth weights for pigs born in litters of various sizes.

those which are conceived. This is somewhat similar to HAINES' (1931) finding that the lowest *mortality* in guinea pigs was in litters of two or three rather than in litters of one or in very large litters.

Of the variance for all pigs, 7.0 percent disappears when the effects of differences in litter size are removed. The corresponding figure obtained in studying only the pigs born alive is 7.7 percent. The effect of litter size is highly significant. Yet the seven percent of variance removed by excluding the effects of litter size appears small in contrast with the ninety-three percent of the original variance still remaining when attention is confined to pigs all of which were born in litters of the same size. A difference of one more or one less young in each litter has much less effect on the average birth weight in swine than in guinea pigs (HAINES) or in sheep (unpublished data of the IOWA STATION).

In the last column of table 2 are shown factors for correcting birth weights to a standard litter size of nine pigs born. These factors are based on all four sets of data with due regard for the fact that the mean birth weights in the four sets of data are not identical. The correction factors are somewhat arbitrarily adjusted to give a smooth curve with an increasing birth weight up to litters of four pigs and then a birth weight which decreases rapidly at first but somewhat more slowly with each additional pig as the litter size passes nine to eleven. The smoothing was undertaken on the hypothesis that most of the sharp irregularities observed in the actual curves are sampling errors. The numbers of extremely small and extremely large litters are so few that the correction factors for litters smaller than four or larger than twelve must be regarded as much more tentative than the others. The whole set of correction factors is presented for tentative use until extensive study of more data will justify their revision. In using these factors, the actual birth weight should be multiplied by the appropriate factor to obtain the most probable estimate of what that birth weight would have been if the pig had been born in a litter of nine, all other conditions remaining the same. For example, a pig actually weighing 3.8 pounds in a litter of four would be estimated to have weighed 3.42 pounds ($3.8 \times .90$) if it had been born in a litter of nine, while a 3.8 pound pig actually in a litter of twelve would be estimated to have weighed 3.99 if in a standard litter of nine pigs.

How litter size exerts its effect

Litter size might affect birth weight either by changing the intensity of competition among the developing fetuses for the available food supply, oxygen, space, et cetera, or by affecting the length of the gestation period so that larger litters might be born at an earlier stage of development than smaller litters. WRIGHT (1921, see page 570) found in guinea pigs that "size

of litter has much more effect on birth weight by reducing the rate of growth of the fetuses than by causing early parturition." The data necessary for a similar analysis for swine are the three correlations between birth weight (B), litter size (L), and length of gestation period (G). The other symbol (R) in figure 3 stands for the growth rate of the individual fetus. The solution is rigorously correct only if the causal relations are pictured correctly in figure 3 and if those relations are linear. The relation between litter size and birth weight is not quite linear but the discrepancy thus introduced is small. The needed correlations were computed directly (in the course of an analysis for another purpose) for the Poland Chinas

FIGURE 3.—Path coefficient diagram showing that the relation of litter size to birth weight results mostly from intra-uterine competition, rather than through intermediate effects on length of gestation.

(1261 males and 1192 females) included among these pigs. Two of those correlations may also be deduced for the larger population from the analysis of variance. These primary correlation coefficients are:

	r_{BL}	r_{BG}	r_{LG}
Computed directly for Poland China pigs	-.261	+.051	+.013
Deduced for all pigs from reduction in variance	-.265	+.141	

Figure 3 shows the solutions when the directly computed coefficients are used and also when the deduced coefficients are used and r_{LG} is assumed to be +.013 as it was in the smaller group of data. The two solutions differ but slightly, especially with reference to the path through which litter size exerts its influence. Competition between the fetuses is indicated as the major way in which litter size affects birth weight. The effect by way of an influence on gestation length is even less important than in guinea pigs. The slight errors in assuming linearity can scarcely

have been important enough to invalidate these conclusions. Parenthetically it should be stated that gestation length is comparatively stable in swine, the mean for these 506 litters out of gilts being $115.76 \pm .06$ days with a standard deviation of 1.89 days. The extreme lengths were 107 days and 127 days.

Breed differences in birth weight

When the data are grouped according to the breed of the sire and the dam there are nine classes. Since not all breeds were equally represented in each year, it is not possible rigorously to separate breed differences from environmental factors which may have varied from year to year. The variance within breed is 3.9 percent less than the original variance in birth weights among all 3639 pigs. Among the pigs born alive the variance is reduced 6.8 percent by taking out the difference between breed means. These effects of "breed" are highly significant although not quite as important as litter size. The extent to which the effects of year possibly are included under "breed" will be discussed later.

Yearly variations in birth weight

Environmental conditions, such as weather, kind and quality of feeds, details of management, et cetera, naturally varied somewhat from season to season and may have influenced the pre-natal development of the pigs. In table 3 is shown the analysis of variance when the birth weights of the pigs are grouped according to the year in which they were farrowed. The effect of "year" is highly significant (4.714 is about 16 times .285) and yet the original variance (.302) is reduced only about 5.6 percent (to .285) when only pigs born within the same year are considered. The corresponding reduction among the pigs born alive is 6.4 percent.

TABLE 3
Analysis of variance in birth weights by years.

VARIANCE DUE TO	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	STANDARD DEVIATION
"Year"	14	66.00	4.714	
Other causes	3624	1032.00	.285	.534
All causes	3638	1098.00	.302	.549

Combined effects of year and breed

When year and breed are treated separately each is found to be associated significantly with variations in birth weight. If each breed had constituted a constant proportion of the pig crop in all years, the combined importance of breed and year could have been obtained by adding the separate figures together (possibly plus a small amount for genuine dif-

ferences in the way different breeds reacted to differences in the environment from year to year). Since they were not so distributed it is *a priori* likely that each, figured separately, contains some of the effects of the other and that a simple addition of their separate effects would result in an exaggerated estimate of their combined importance. Actually only 7.6 percent and 11.4 percent of the original variance for all pigs and for live pigs respectively disappears when the pigs are divided into groups within each of which all pigs belonged to the same breed and were born in the same year. These figures, while larger than for either "breed" or "year" alone, are smaller than the sums (9.5 percent and 13.2 percent) of their effects when figured separately. It is thus clear that "breed" and "year" when figured separately each include some effects of the other. The figures for "year and breed" (7.6 percent and 11.4 percent) express their combined importance but it does not seem possible to estimate very closely from these data the separate importance of each.

Does the sire influence the birth weight of his pigs?

Litter-mates are subject to similar environmental conditions during their intra-uterine life. This might well make the dam more important than the sire in affecting birth weights, even though both sire and dam contribute equally to the genes of the embryo. To find whether the boar had any effect at all upon the birth weight of his pigs, all pigs born in the same year and sired by the same boar were grouped together. It was found that 6.2 percent and 7.0 percent of the variance for all pigs and for those born alive was eliminated when this was done. These figures are to be compared with those for "year" alone (5.6 percent and 6.4 percent). Even though the variance eliminated by holding sire constant within "year" is but slightly more than that eliminated by "year" alone, *P* is about .01 and it appears certain that the boar had some effect on the birth weights of his offspring. Table 4 shows the data which support this conclusion.

TABLE 4
Variance by years and by sires.

VARIANCE DUE TO	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE
"Year"	14	66.00	4.714
Boar within year	18	10.29	.572
Remainder	3606	1021.71	.283
Total	3638	1098.00	.302

The additional portion of the variance which disappears when sire as well as year is "held constant" provides a basis for estimating the cor-

relation between sire's genotype (that is, the sum of the average effects of the genes possessed by him) and pig's birth weight. Thus $\sqrt{.062 - .056}$ gives .08 as an estimate of the correlation between paternal genotype and offspring's birth weight. The difference between .062 and .056 when multiplied by four leads to the estimate that between two and three percent of the variance in birth weight is due to differences in the genes possessed by the pigs themselves. This estimate must be regarded as quite provisional for the following reasons:

1. The indirect method of its computation provides opportunity for sampling errors to be magnified, thus making it possibly in error in either direction.
2. If part of the difference between years is really genetic (as may well have been the case), this estimate is too low.
3. Variance due solely to dominance or to complex non-cumulative interaction of genes is not included in this estimate.
4. Assortative mating within years (if that occurred) would have made this estimate too high.

While the estimate that in these data a little less than 3 percent of the variance in birth weight is due to differences in the genes possessed by the pigs themselves must therefore be considered highly tentative, it seems as reasonable an estimate as can be made at present.

In crossbreeding experiments between highly inbred strains of guinea pigs, WRIGHT (1922) finds that: "Birth weight depends largely on the dam — about three-fourths — and only one-fourth on the breeding of the young." His statement here concerns the average birth weights of all pigs from each cross and does not include the individual variation from pig to pig which is so prominent in the variance discussed in the preceding paragraph.

GREGORY and CASTLE (1931) state that embryonic development in the rabbit proceeds at a more rapid rate in rabbits of large races than in rabbits of small races. The higher rate of development of these rabbits is influenced by the sperm, as well as by the egg and may be supposed to be induced by chromosomal genes. They used races selected expressly because of a wide contrast in size and hence would be expected to find a larger proportion of genetic differences than in these swine which were selected with no conscious attention to birth weight and without any attempts to secure extreme contrasts in adult size.

Effects of differences between reasonably good rations

To determine whether differences in the moderately good rations fed to these sows had any effect on the birth weights of their pigs, the birth weights within each year were grouped according to the ration the dams

received. Table 5 shows the variance between pigs born in the same year but classified according to the ration of their dams. Year and lot together account for 9.6 percent and 10.3 percent of the variance in birth weight for all pigs, and for pigs born alive. The effect of ration is relatively small, yet statistically quite significant. The rations were all reasonably good ones. Had extreme rations, such as corn and water alone in dry lots, been included, no doubt a more extreme effect of ration would have been found.

Length of gestation period

According to CARMICHAEL and RICE (1926) the length of the gestation period does not appear to have any appreciable effect on the birth weights of the pigs. However they found a slight tendency for some of the litters which were carried longer than the average to have fewer pigs than those that were farrowed earlier. This observation suggests that the effect of gestation length on birth weights is involved with the effect of variation in litter size, as is discussed earlier in this paper under the discussion of litter size. In the present study when gestation period was "held constant" about 2.0 percent of the variance in birth weights was decreased for all pigs and 3.5 percent for live pigs. This effect is statistically significant, although not very important.

TABLE 5
Analysis of variance in birth weights by lots.

VARIANCE DUE TO	DEGREES OF FREEDOM	SUM OF SQUARES	STANDARD DEVIATION
"Year"	14	66.00	4.714
Lot within year	52	55.30	1.064
Other causes	3572	976.70	.273
All causes	3638	1098.00	.302

"Condition" and "vigor" of the pigs

Condition and vigor of the pigs were graded at the time of birth. These terms designate certain characteristics of the pigs, such as the state of health, the general conformation and the apparent vitality and strength of the pigs. The precision with which the animals were classified naturally is affected by the personal opinion of the observer in spite of all precautions against this. Condition and vigor can in no sense be regarded as *causes* of the differences in birth weights. They are in large part additional ways of expressing the same things which are expressed in birth weights. The analysis of variance shows roughly how much of what the caretaker saw when he was looking for differences in condition and vigor was also reflected in differences in weights. The variance in birth weights within

groups of pigs given the same grade for condition is 50.7 percent less for all pigs and 37.5 percent less for pigs born alive than that found within the whole group of observations. Similarly 38.4 percent of the mean variance for all pigs (38.8 percent for pigs born alive) is eliminated when the data are grouped according to the grade for vigor.

Weight differences between litter-mates

Litter-mates are more apt to have the same genes than are pigs less closely related than full brothers and sisters. Yet litter-mates are unlike in many genetic factors. Litter-mates also tend to be alike because they developed in the same uterus and were thus exposed to an environment remarkably uniform for members of the same litter but perhaps differing distinctly from litter to litter. Yet there must have been environmental differences from one part of the uterus to another, as perhaps in the crowding or in the blood supply to each fetus. A comparison of the variance between litter-mates with the variance between all pigs, permits a rough estimate of the importance of intra-uterine environment which differs from litter to litter plus genetic differences between litters as contrasted with genetic differences within litters plus "accidents of development"—that is to say, environment which affected differently even pigs in the same uterus.

In a random-bred population the genetic variance between litter-mates would be about half as large as the genetic variance of individuals chosen at random from the whole population. However this stock was not quite random-bred since several breeds and crosses were included. One would expect the genetic variance between litter-mates to be slightly less than half as large as the genetic variance in the entire population, if these breeds and crosses differed genuinely from each other in birth weights. The group studied corresponds crudely to a population of several very slightly inbred lines (unselected for birth weights) with a few crosses between those lines.

The variance in birth weight of litter-mates is 50.7 percent less than that in the whole population. The corresponding figure for live pigs only is 54.6 percent. The portion of the total variance thus eliminated includes that due to all controlled environmental conditions (that is, all effects of environment which were identical for litter-mates) and also probably a little more than half of the genetic differences. The remaining variance (49.3 and 45.4 percent) is that due to environment which differed even among litter-mates and to genetic differences between litter-mates, also including sex.

Using the data for all pigs and subtracting from the 49.3 percent of the variance between litter-mates about half of the genetic portion of the

variance already mentioned in discussing the influence of the sire, and also subtracting the variance due to sex (1.3 percent) there is left about 47 percent of the original variance due to environment not common to litter-mates. Similarly, subtracting from the 50.7 percent of the original variance not found between litter-mates a little more than half of the genetic variance within breeds and the variance between breeds within year (2 percent), there is left about 47 percent of the original variance due to environment which differed from litter to litter but affected all litter-mates alike. This yields the following rough apportionment of the variance due to various causes in these data:

<i>Heredity of the pigs</i>	<i>Percent</i>	
Breed differences	2	
Sex	1	
General	3	
		6
<i>Environment common to litter-mates</i>		
Litter size	7	
Year	5	
Ration	4	
Gestation length	2	
Other	29	
		47
<i>Environment not common to litter-mates</i>		
		47
Total = 100		

The following reservations should be kept in mind in interpreting this apportionment. First, if pig birth weight is largely the expression of genetic differences between dams in somewhat the same way that egg size in poultry is largely the expression of maternal differences, regardless of the kind of sperm which fertilized the ovum, then some of the "Other" environment common to litter-mates is really genetic in origin but depends on the genotype of the dam rather than on the genotype of the pig. WRIGHT (1922) found this to be the case in crosses of inbred lines of guinea pigs. Second, random errors in weighing (as were mentioned in discussing the apparent bimodality of the principal curve in figure 1) would appear as part of the environment not common to litter-mates. Third, differences in weight because some litters had suckled and others had not, would appear as part of the "Other" environment common to litter-mates.

Fourth, variance due to dominance or to non-cumulative interaction of the genes would appear both under environment common to litter-mates and under that not common to litter-mates but most of it would be under the latter. The total amount of variance from dominance or non-cumulative interactions can hardly have been large, however, since the total part played by the heredity of the pigs appears to have been small. Fifth, these proportions apply to these particular data which include a wide sample of rations and years and several breeds but only litters produced by gilts. Had the breeds been selected expressly to secure a wide range in size (as in experiments such as those of GREGORY and CASTLE) the breed differences would no doubt have appeared proportionately larger. Had litters from older sows been included, there would have been an item under "environment common to litter-mates" for age of dam and all the other items would have been reduced somewhat in proportion. Had rations been more extreme in their contrast, ration would have been relatively more important and the others less so. Sixth, a portion of the variance ascribed to "year" may really have been genetic, since none of the dams were used in two years and few of the boars were used more than two years.

For these reasons, and because of the indirect methods by which it was computed, this apportionment must be considered provisional and not securely enough founded to justify any broad generalizations except perhaps the one that the genetic portion of the variance in birth weights within a breed of swine is comparatively small. In spite of these reservations this apportionment seems to provide as complete and reasonable a picture of the general situation as the present data and state of knowledge afford.

SUMMARY AND CONCLUSIONS

1. Birth weights of 3639 pigs in 506 litters farrowed by gilts at the IOWA AGRICULTURAL EXPERIMENT STATION were studied to find the importance of various sources of variation in those weights.

2. The sex ratio of the pigs at birth was 51.1 percent males. The frequency of the sex combinations seemed to be a random expression of $(p+q)^n$. The sex ratio was not related to litter size. Males were significantly but very slightly heavier than females.

3. The mean litter size for all breeds was $7.19 \pm .07$ pigs. The relation between litter size and birth weight is slightly curvilinear, the maximum birth weights being in litters of about 3 to 5 pigs each. Tentative factors are suggested for correcting birth weight to a standard litter size of nine pigs born.

4. The following portions of the variance in individual birth weights disappeared when each of the named variables in turn was held constant but the others were allowed to vary:

VARIABLE	PORTION OF VARIANCE IN PERCENT WHICH DISAPPEARED	
	AMONG ALL PIGS	AMONG LIVE PIGS ONLY
Sex	1.3	1.1
Alive at birth	4.8	..
Litter size	7.0	7.7
"Breed" alone	3.9	6.8
"Year" alone	5.6	6.4
"Year" and "breed" together	7.6	11.4
Year and sire together	6.2	7.0
Year and ration together	9.6	10.3
Length of gestation	2.0	3.5
"Condition" of pig at birth	50.0	37.5
"Vigor" of pig at birth	38.4	38.8
Litter	50.7	54.6

Not all of these variables are independent of each other but many overlap considerably. Hence (and because not all causes of variation are included) these percentages do not add up to 100 percent.

5. A rough approximation is given of the relative importance of heredity and environment as causes of variation in birth weight in these data.

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