An Anatomical and Chemical Study of Inbred and Crossbred Strains of Guinea Pigs

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Introduction

In the stock of guinea pigs developed by the Bureau of Animal Industry, U. S. Department of Agriculture, striking differences in the various inbred and crossbred lines have been noted. Wright (31, 32) [1] and Wright and Eaton (34) observed that the groups early differentiated into well defined lines varying in live weight, mortality percentages, and fertility and that this differentiation has persisted after several generations of close inbreeding. Wright and Eaton (33) discussed the development and increase of a defect known as otocephaly in one of the inbred strains and Eaton (5) has shown the development of a difference in color pattern in one of the inbred lines. McPhee and Eaton (22) have shown that there is a genetic difference of growth rate between the various lines. Eaton (6) has discussed some of the factors which determine weight at birth and during other periods of life, in which length of gestation period, litter size, early gains and condition of dam at and preceding parturition play an important part. Eaton (7) has summarized the changes taking place in five inbred lines and a control stock through a period of 25 years, in which the most marked change has been a decrease in fertility. Other changes are a decrease in weight at birth and weaning in most of the families and an increase in mortality percentages in all.

Wright and Lewis (3) have shown that there is a difference in

[1] Reference is made by number (italic) to "Literature cited," p. 53.

the degree of resistance to tuberculosis between the various lines, among which one of the inbred families shows a higher resistance than the non-inbred control stock, and hybrids of this resistant family with others less resistant show increased resistance over either parent line. Lewis and Loomis (17, 18) have shown differences between the families in their capacity to produce antibodies and differences in ulcerative types of lesions produced upon inoculation with cultures of tuberculosis bacilli. Loeb and Wright (19) and Loeb and McPhee (20) have shown that the families differ in their response to various types of skin and other tissue transplants. Tissues from some of the families will not grow or grow only with considerable difficulty when transplanted to another family, while transplants between others take growth fairly readily. Transplants from a hybrid to one of the parent families or vice versa grow more readily than transplants to wholly unrelated animals.

The following study was planned to form another link in the chain of genetic differences which have been shown in the previous investigations.

The purpose of the present study is (1) to determine the differences in weight of the various organs and glands, differences in skeletal measurements, and composition of the blood between the several genetic groups of guinea pigs; (2) to determine the inter-relation of parts and the variations within a single line; and (3) to endeavor to apply the results found in interpreting some of the variations and conditions found in classes of farm livestock.

Material and Methods

The material used for this study was families 2, 13 and 35 of the inbred lines of guinea pigs, the control stock B, CY, CY-1 and CY-2 which are F_1, F_2 and F_3 generations respectively of crosses between families 2 and 13; CP and CP-1, F_1 and F_2 generations of 13 by 35 cross; and C-0 and C-1 which are for the most part F_1 and F_2 of 2 by 35 cross. Males were used mostly, though a few females were used for comparison of sexes and to increase numbers in some of the groups.

The data taken include live weight of the animal, weight after bleeding for the purpose of checking on weight of the carcass and parts, and to determine the experimental error; weight of heart, lungs, liver, kidneys, eye balls, spleen, pituitary, thyroid, adrenals, testicles, front quarters, hind quarters and loin; length of small and large intestines; serum calcium and inorganic phosphorus of serum; catalase content of blood; weight of scapula, humerus, ulna and radius of the foreleg, and femur, tibia and fibula of the hind leg; length of humerus, ulna, femur and tibia. Length and width of spleen and color of fat in some of the animals were recorded.

The animals were weighed to the nearest tenth of a gram on a Troemer balance, then etherized and bled by severing the blood vessels in the neck with a pair of scissors. The blood was collected in an evaporating dish in which was a small amount of powdered sodium citrate to prevent coagulation. After wiping all blood out of the neck with cotton, the animal was again weighed. One-half cubic centimeter of the blood was taken as soon as drawn and analyzed for catalase content, by determining the amount of oxygen evolved in 1 minute from 10 c.c. of commercial H_2O_2 diluted to 30 c.c. with distilled water. The equipment and method was a modification of the one described by Burge (2) for determining muscle catalase. It was found that 0.5 c.c. of blood would evolve enough oxygen from the above stated amount of H_2O_2 to nearly, or in some cases, more than fill a 100 c.c. burette. The reaction was very rapid and was completed in less than 1 minute. The amount of oxygen evolved was expressed in c.c. adjusted to standard conditions of 0° C. and 760 m.m. pressure. The remainder of the blood was centrifuged and the serum analyzed for Ca and inorganic P, the former by the Clark-Collip modification of the Kramer-Tisdale method, and the latter by the method of Fiske and Subbarow, both of which are described by Hawk and Bergeim (13).

The glands and organs were next removed, trimmed of fat and other adhering tissue, cleaned of excess blood with absorbent cotton, placed in ground-glass stoppered weigh bottles and weighed on a chemical blance to 0.1 mg. Such fineness of weight was probably not necessary for the larger organs such as lung, liver, kidneys, etc., and for practical purposes only hundredths of a gram have been considered in the weights of these organs. The pituitary was removed by opening the top of the skull with bone snips, lifting up and laying back the brain, thus exposing the pituitary under a thin but tough membrane in a slight depression in the base of the skull just posterior to the optic chiasma. The heart was slit to remove any clotted blood from its various chambers.

In addition to weighing, length and breadth of spleen were measured to the nearest half millimeter. Intestines were removed, trimmed from their supporting mesentery and laid out on the table without stretching, for measurement of length to the nearest tenth centimeter, large and small intestine being measured separately. The small intestine includes the portion from stomach to caecum, and the large intestine from caecum to anus. After weighing, the pituitary, thyroids, adrenals and testicles or ovaries were fixed in Regaud's formol-bichromate fixative and sent to Dr. J. M. Wolfe of Vanderbilt University Medical School who is making a study of the various cell types of the pituitary and their relation to other glands. The other organs were discarded after weighing. The front and hind legs were removed and weighed as front and hind quarters. The skin was removed as far down as the wrist and calcaneus respectively. The scapula and its muscles were included in the front quarter, but the muscles connecting the limb to the body were trimmed close around the three borders (vertebral, coracoid, and glenoid) of the scapula. The hind quarter was trimmed out close along the ischium to the head of the femur, then straight out to the attachment of the sartorius muscle to the lumbodorsal fascia. The loin included the portion of the back from immediately behind the last rib to the center of the acetabulum. The lumbodorsal fascia and obliquus abdominis externus and internus muscles were trimmed close to the sides of the longissimi dorsi muscles, so that only the heavy muscles lying along the dorsal and ventral surfaces of the lumbar vertebrae were included. The two front and hind legs were weighed together as front and hind quarters respectively. The left front and hind legs were saved for bone measurements after boiling off the meat. The remainder of the carcass was weighed and recorded as waste. After adding together the weights of all the separate parts, the sum should check with the weight after bleeding. That the computed weight never checked exactly, is due to loss of some blood on the instruments and to evaporation from portions of the carcass exposed to the air, but the difference was never greater than 2 percent of the actual weight after bleeding. The average experimental error was about 1.5 percent.

Results

Original Data on Weight Measurements

Live Weight - Previous publications mentioned above have shown that the various inbred and crossbred lines differ from one another in live weight. The weight for each group is shown in Table I. It will be noted that inbred Family 2 is the lightest while the control stock B is the heaviest, with a difference of over 300 grams. Families 13 and 35 differ only 37 grams in mean live weight. Crosses between families 2 and 13 are approximately intermediate in weight between the parent lines and the greatest difference between F_1, F_2, and F_3 of this cross is only 11 grams. Cross 13 by 35 averages heavier than either parent line in the F_1 generation and the F_2 is about equal to the weight of family 35. C-0 and C-1 are for the most part F_1 and F_2 respectively from crossing family 2 and 35. A few have family 32 or 39 for one of the parents in place of family 35. The weight of the F_1 generation (C-0) is approximately equal to the weight of family 35 and the F_2 (C-1) about the weight of family 2, suggesting, perhaps, segregation of weight. The weight of the F_1 generation of 2 by 13 cross differs somewhat from the result found in a previous study (22) where the weight of the crossbreds followed more closely the weight of the heavy parent line. The discrepancy here, however, may be due to the small numbers involved.

The standard deviations of the different groups, shown also in Table I, vary from 40 grams in CY to 152 in CP-1. In general, the magnitude of the standard deviations is in keeping with the live weight. The coefficients of variability (Table I) give a better idea of the amount of variation within a line. CP-1, C-1, C-0 and family 13 show high variability while the others are relatively low. The average variability for all 11 lines studied is less than 11 percent, which is not considered large. It will be noted that some of the crossbred lines are less variable than the inbred lines 2, 13, and 35. This may not be significant, however, in view of the small number of observations in these particular cases.

The differences in weight between family 2 and all of the other groups is significant when tested by Fisher's (9) table for the values of t and p. Differences between family 13 and 35, and crosses involving family 35 are not significant, nor those between B and CP. The only significant differences between the remaining groups are between CP and the CY group of crosses and between C-0 and CY-1. Table III shows the differences which are significant.

It will not be possible to point out in detail the various points of difference between the weight and variability of the different organs studied. Therefore, only special outstanding features will be noted. The details of weight, standard deviation and coefficients of variability will be found in Tables I and II. In connection with the coefficients of variability, the various measurements have been grouped as of high, medium and low variability. The comparison of variation of the various organs and of the different lines is shown in Table IV.

Front Quarters - The weight of the front quarters is smallest in family 2 (47.4 gm.) and greatest in B (67.7 gm.). Families 13 and 35 differ only 2.8 grams, while the maximum difference between CY, CY-1 and CY-2 is only 1 gram. The standard deviation of the weight of the front quarters is not great, the maximum being about 8 grams. Family 35 has the lowest coefficient of variability (5 percent) and C-1 the highest (17 percent). The average variability for the 11 groups is 10.4 percent which is only 0.4 percent lower than the variability of the total weight of the animals. The difference between family 2 and all other groups is significant. Family 13 differs significantly only from B and the CY groups. Family 35 differs significantly from all groups except CP-1 and C-0, while B differs from all the groups except CP. The other significant differences are CP and C-0 with the CY groups.

Since the different groups show so much variation in live weight it was thought that better comparisons could be made of the differences between the groups by expressing all weights as a percentage of live weight, thereby making live weight constant. Expressed thus, the front quarters are 6.69 to 7.21 percent of the live weight, (Table II). The maximum standard deviation when expressed as percentage of live weight is about 0.6 percent. The coefficients of variability are much less when expressed as percentage of live weight than when actual weights are given. The highest variability is in B with 9.3 percent and the average for the whole series 6.7 percent. The only significant differences between groups when expressed as percentage of live weight are between family 2 and 13, 35, B and CP; between families 13 and 35, and CY and C-O; and between B and C-O.

Hind Quarters - The hind quarters range from about 12 to 15 grams heavier than the front quarters. B and CP are the heaviest, weighing 81.8 and 81.4 grams respectively while family 2, weighing 59.2 grams, has the lightest hind quarters. The CY groups vary less than 2 grams from one another. The standard deviation of the hind quarters ranges from nearly 5 to over 100 grams and the coefficient of variability from 7.3 to 15.7 percent with an average of 9.7 percent for the whole population. Expressed as percentage, the hind quarters form about 8 percent of the live weight of the animal. B and family 13 are most variable, and with the exception of C-1 which has only two observations, CY is the least variable.

All groups differ significantly from family 2. There are a few significant differences between other groups. Expressed as percentage of live weight, significant differences disappear between family 2 and CY, CP and CO groups, except CP-1; only 13 and the CY groups are significantly different, and B and all other groups except CP-1 and a few scattered groups.

Loin - Weight of loin agrees very closely with the weight of front quarters. Family 2 has the lightest loin, with a weight of 45.3 grams and B the heaviest, weighing 67.2 grams. Families 13 and 35 differ from each other by only 1.5 grams while the maximum variation in the CY group is 1.8 grams. CP and B differ by only 0.6 gram. The coefficient of variability for loin weight is greater than that for the quarters. CP-1 has a variation of 23.8 percent and family 35 with the lowest has a value of 8.9 percent. The average coefficient of variation for all lines is 13.3 percent.

The differences between most lines are significant. Among those which are not are family 13 and 35, CP, CP-1 and C-O; and B and CP. Differences between the CY groups and CP and CO are significant. Expressed on a percentage basis, the loin is about 7 percent of live weight. Family 2 and 13 are equal and B only 0.04 less. CY-1, CP and C-O are slightly over 7 percent of live weight. None of the differences are significant except 2 and CY-1, and B and CY-1.

Heart - The weight of heart in all lines is slightly over 2 grams, or approximately 0.3 percent of the live weight. The actual weight in the different lines is so similar that it hides the real variability in heart weight which is emphasized by the coefficients of variability. In family 2 the percentage variability is 13.6 and in family 13, 2.2 percent. The crossbreds have coefficients of variability of 10 and 11 percent except CY which is the lowest of the whole group with a value of 4.1. Family 35 also has low variability of heart weight, the value being 5.2. On a percentage of live weight basis, the highest variability of heart weight is in CP-1 with a value of 15.9 percent and families 2 and 13 follow closely with values of 13.4 and 13.5 respectively. The variability of family 35 is raised to 8 percent when expressed as percentage of live weight. The value of the coefficients of variability is somewhat less in the other lines when expressed on a percentage basis than when actual weight is used.

Differences are significant between family 2 and all other groups except CY and CY-2. Expressed as percentage of live weight, the significance of the difference between family 2 and CY-1 and CP-1 disappears, differences between family 13 and all lines except 35, CP, CP-1 and CO become significant, and all differences with B are significant.

Lungs - The lungs are quite variable in weight whether expressed as absolute weight or as percentage of live weight. The average weight of lungs is equal in B and CP, and the variation between families 13, 35 and CY-1 is small. Families 2, CY and CY-2 have lungs considerably lighter than the others. Expressed as percentage of live weight the value lies between 0.6 and 0.7 percent except in two lines, CY-1 (0.71) and CP-1 (0.84). In actual weight the lungs of family 2 differ significantly from all groups except CY and CY-2. In family 13 they differ significantly from B, CY, CY-2 and CP-1. Family 35 differs significantly from CY and CP. B differs significantly from CY, CY-2 and C-O. If expressed as percentage of live weight there are only 10 significant differences out of a possibility of 45.

Liver - The liver appears quite variable, but because of its greater weight, the variation is actually less than in many other organs. B and CP-1 have the heaviest liver and family 2 the lightest. The liver forms a little over 3 percent of the body weight. There are several significant differences between the groups with the liver weight expressed in actual value, but on a percentage basis, several of these differences disappear. The differences which do persist are those between the very heavy and the very light groups.

Kidneys - The kidneys do not show large actual differences in weight among the different groups, and very few of these are significant, but expressed as percentage of live weight there is considerable variation and a large number of the differences become significant. One notable fact in connection with the kidneys is that family 2, the lightest in live weight, has a kidney which ranks among the highest in actual weight, and on a percentage basis, is the heaviest of all the lines. The variability in kidney weight is low as shown by the coefficient of variation.

Spleen - The spleen is similar to the kidneys in its relationship to live weight and to the different groups. Again family 2 has a heavy organ, ranking second in spleen weight; only C-O, a crossbred line with family 2 ancestry, has a heavier spleen. In percentage of live weight, family 2 spleen ranks first. Family 35 spleen ranks among the smallest in actual weight and is the smallest in percentage weight. The spleen of family 35 differs in shape quite markedly from that of the other lines and will be mentioned more in detail later. The spleen falls with the group of organs having high variability. There are very few significant differences between spleen weight when actual weight is used, but most of them become significant when expressed as percentage of live weight.

Eyes - It has been long observed that the eyes of family 35 appear much more prominent than in other groups, giving the animal a sort of "pop-eyed" appearance. The actual weight of the eyes in this family is greater than in any other line, but expressed as percentage of live weight, falls considerably below several others. Family 2 has the heaviest eyes in proportion to live weight. Eyes are only moderately variable in weight. There are several groups which differ significantly from one another whether expressed in actual weight or as percentage of live weight.

Pituitary - Variations in the actual weight of pituitary glands agree fairly well with live weight. The actual weight of pituitary in family 2 is rather low, though not the lowest, yet in proportion to live weight is the greatest. Family 35 has lowest pituitary weight, both in actual and percentage weight. B has the highest actual pituitary weight, but ranks with the CY group of crossbreds in percentage weight. The variability of pituitary weight is medium. Family 35 and B are significantly different from other groups in actual pituitary weight and families 35 and 2 from other groups on a percentage basis. Most other groups do not show significant differences.

Thyroid - Thyroid glands in families 13, CP and CP-1 are about equal, and the smallest are in families 2 and CY-2. B has the smallest thyroids in proportion to live weight. The variability of thyroid weight is high. There are few significant differences either in actual or percentage weight.

Adrenals - With the exception of C-O, family 2 has the largest adrenal glands according to actual weight and B the smallest. In percentage weight family 2 ranks highest and B lowest. This is a rather peculiar relationship, the group lightest in live weight possessing the heaviest and the line with the greatest live weight, the smallest adrenal glands. There is a high coefficient of variability for the adrenal glands. There are very few significant differences in actual weight except between family 2 and the other groups, while on a percentage basis the differences between families 2 and B and the other groups are significant.

<u>Testicles</u> - The actual weight of the testicles appears quite variable, but expressed as percentage of live weight, much of the variation disappears. Family 2 has the lightest testicles and CP the heaviest. All of the lines heavy in mature weight have testicles weighing over 5 grams except family 13, which falls only 0.04 gram below this weight. The weight of testicles in the CY groups is between 4 and 5 grams. Expressed as percentage of live weight the testicles of families 2, 13 and B are very similar, and the remaining groups are also quite similar among themselves. The testicles are among the group of organs with medium coefficients of variability. The significant differences in testicle weight are between family 2 and all other groups and in a few other isolated cases. When expressed as percentage of live weight the difference between family 2 and the other groups lose their significance, but 13 and B differ significantly from the others.

<u>Intestine Length</u> - Small intestines - The length of intestines in several groups varies by only a fraction of a centimeter, while those in other groups are considerably longer. Thus in families 2, CY-1 and CY-2 there is a maximum difference of 0.8 cm. In family 13, 35 and CP-1 which averages about 4 cm. longer than the first-named groups the maximum difference is 1.1 cm. Four other groups are more variable, ranging

in length from 160 to 170 cm. The coefficient of variability of intestine length is smaller than that of the weight of any of the organs, being 5.36 percent. Only a few differences in intestinal length are significant; most of them are between B and the other groups.

Large Intestine - The length of the large intestine averages slightly over 48 cm. shorter than the small intestine. The maximum range in length is 10.5 cm., ranging from 106.3 to 116.8 cm. The coefficient of variability is small varying but 0.07 percent from that of the small intestines. There are fewer significant differences than is shown by the small intestine and no uniformity of groups which show significance.

Study of Family 2 Age Groups

Since family 2 was the largest group studied, it was decided to make a more detailed analysis of this group, especially of the age relationship to the different characters studied. The guinea pigs used in the study were animals a year old or over, since according to McPhee and Eaton (22) 90 percent or more of the weight at two years of age is attained at this time, therefore differences due to growth of different parts should largely be eliminated by the time an animal is one year old. Bessessen and Carlson (1) show that most of the organs increase in proportion to body weight and remain relatively stable when maturity is reached. The sex organs, however, grow slowly until puberty, then increase very rapidly, and after the normal reproductive period is passed, gradually decrease in weight. The animals were divided into age groups of 90-days interval, beginning at 360 days. Those over 900 days were all included in a single group. Average weights of the different organs and parts for the different age groups are shown in Table V. It will be seen that live weight for each group does not increase in every case with increase in age. Therefore some groups are either heavier or lighter than normal for that particular age. This will necessarily affect the weight of other body parts if there is a close correlation between live weight and body parts. It will be shown later in this paper, however, that only a few of the correlations between body parts and live weight are high.

The weight of most of the organs in age group 1 differ significantly from those of the other age groups. Weight of kidneys, eyes, and adrenals seem to follow age a little more closely than other organ weights. Testicles appear to decrease in weight with increase in age. The low average testicle weight of the last group is undoubtedly due to males which had passed their active breeding age, and whose testicles were in a state of degeneration. The group over 900 days of age also shows differences which are significant from the other groups in weight of thyroid, adrenals and testicles. Significance of differences between different age groups and between males and females of family 2 is shown in Table VI.

When the weights of the organs are expressed as percentage of live weight there seems to be less relation between age and weight than when the actual weights of the organs are used. Adrenals and testicles appear to be most consistent in their age-weight relationship. These facts are shown better by the coefficients of correlation between age and weights of various parts. Among the significant correlations are those between age and weight of heart, kidneys, eyes, and adrenals. The highest correlation is between age and weight of eyes (0.887) and adrenals second with a value of 0.744. Expressed on a percentage basis, correlations between age and percentage weights are all lower than when actual weights are used. The same correlations previously mentioned as significant still hold. The correlations between age and liver weight are negative, but small, probably indicating lack of correlation rather than a real decrease in liver weight with increasing age, but with the testicles the negative correlation is real; the value for actual weight is -0.417 and with percentage weight -0.854.

At this point differences between males and females in family 2 may be discussed. In live weight there is only 10 grams difference between males and females. Weight of front and hind quarters and loin are less in females than in males. Heart and liver weights show practically no difference. Lungs are slightly heavier in the females. Kidneys, spleen, eyes and thyroid are distinctly heavier in females than in the males, while pituitary weight is exactly the same in both sexes. Adrenals are slightly heavier in females. Expressed as percentage of live weight, the difference in weight of hind and front quarters between males and females is significant, also the differences in kidneys, spleen, eyes and thyroid.

Correlations

Coefficients of correlation between various measurements were calculated in families 2, 13 and B as it was thought that the numbers of observations in these groups only, warranted any degree of significance to whatever correlation might exist. Correlations are shown in Table VII.

Live weight was correlated with all other measurements. Correlation with front and hind quarters and loin are high in inbred families 2 and 13, but in B, the non-inbred control stock shows correlations considerably lower in case of hind quarter and somewhat lower with front quarter and loin. Correlation between live weight and heart weight is .384 in family 2, .446 in family 13 and .735 in B. Correlation between live weight and liver weight shows the same relation in these lines and with almost the same values. Correlation between live weight and lungs, kidneys and spleen is low in all three lines except for the spleen in family 2 which has a correlation only of medium value (.40). Eyes and live weight have appreciable correlations in all three groups. Pituitary weight and live weight have a low correlation, being highest in family 2, with a value of .32. Thyroid, adrenal and testicles have about the same correlation value with live weight in family 2, but show wide variation in 13 and B. Adrenals have a low correlation with live weight in these two groups while thyroid and testicles have correlations above .4 in both groups. Correlation of live weight with length of small intestines in the three groups is nearly equal and above .4 in value. The correlation with large intestine is nearly equal to that with small in family 2, but greater in both family 13 and B.

Correlations between the quarters and loin are high in all groups, as might be expected, since they are portions of the whole, and because of their anatomical relation to the animal body and to each other. Correlations are higher in family 13 than in 2 and lower in B than in either of the other groups. When the percentages which these parts form of the animal's live weight are correlated, the uniformity of the correlations disappears and changes in relationship, family 13 and B having high correlations and family 2 low.

Correlations of heart and lung weights are low in all three groups whether expressed in actual weight or in percentage weight. Heart and liver shows a gradually rising correlation from family 2 with a value of .34 to a value of .68 in B with family 13 between these values. Percentage weight correlations of heart and liver are small. Heart and kidneys show significant correlation values in all three groups, both with actual weight and percentage weight. The values in family 2 are the highest. Heart and spleen weight show no striking correlations either with actual or percentage values. Heart and pituitary weight show appreciable correlation values in family 2 both in actual and percentage weight but not in family 13 or B. Thyroid, adrenal, and testicles show no significant correlation values except possibly heart and adrenal in family 2, both for actual and percentage weight. Heart weight and intestine length show very little correlation.

Lungs, liver, kidneys and spleen are correlated only with the pituitary, thyroid and adrenals in groups 13 and B. Lungs and liver show a fair correlation (.45) in family 2, but with kidneys and spleen the values are low. Weight of lungs correlated with weight of pituitary, thyroid and adrenal, both as actual and percentage weights, show correlation values of nearly .5 in family 13, but in the other two groups are low. Weight of lungs by intestine length shows practically no correlation.

None of the correlations of liver weight with the remaining organs and glands is of such magnitude as to suggest relationship except in B with adrenal weight where the value is .72. Weight of kidneys shows a fair correlation with spleen, pituitary and adrenals in family 2, but is low in the other lines except with adrenal weight in B. All the spleen correlations in the three groups are low. Pituitary weight with thyroid, adrenals and testicles show high correlation values in family 13 in both actual and percentage weights, but not in the other groups. Thyroid and eyes show only a fair correlation in family 2 (.45). Correlations between thyroid and adrenals and testicles show correlation values above .5 in family 13. Adrenals and testicles show a negative correlation in family 2. This is because of the low testicle weight and the high adrenal weight. Correlation between intestine length is high in 13 and B.

Since age was found to have an influence on some of the weights in family 2, age-weight correlations were calculated for the various measurements made. Age and live weight give a rather small correlation, even though the age distribution in family 2 is rather wide. Age and heart weight seems of significant value only in family 2. Age and kidneys and spleen weight are of appreciable size in family 2. Age and eyes in all three groups have high correlations. Pituitary and age are high in 13, and thyroid and age in B, while adrenals and age are high in both

2 and 13. Testicles and age have a high negative correlation in 2, but in 13 and B are of no significance. Intestine length and age, and weight of quarters and loin with age, show no significant correlation values.

Ratios

Bone to meat in quarters

In order to determine approximately the relation between bone and meat in the quarters, the weight of scapula, humerus, and ulna and radius of the left arm were added and multiplied by 2 and compared with the total weight of the front quarters. Similarly, femur and tibia and fibula were compared with total weight of hind quarters. By this method, the foot bones and patella are not included in bone weight of the quarters, but since there is so little meat on the feet, probably very little difference is made in the actual ratios and the value obtained by the method as described. The weight in grams of bone in hind and front quarters and the percentage which this weight is of total weight of quarters, with standard deviations and coefficients of variability are shown for each group in Table VIII.

The bones weighed about 6 or 7 percent of each quarter. The differences between family 2 and all groups except the three CY groups are significant for both front and hind quarters. Differences between families 13 and 35, 13 and B, and 13 and CP are not significant for either quarter. B and Family 35 show significant differences with the CY group, and differences between CP and the CY group are significant. The coefficient of variability of percentage of bone to meat is not greater than

11 percent in any group, which is considered low. Significant differences of percent of bone to total quarter is shown in Table IX.

Spleen length and width

There is considerable variation in spleen shape in the different lines of guinea pigs. In most of the lines the spleen is long and narrow, but in one line, family 35, the spleen is very much shorter than in the other groups and straight across the ends rather than curved or pointed as in the long spleens. The average length and width of spleen and ratio of length to width is shown in Table X for each of the lines. In family 2 the spleen is more than 2 mm. longer than that in any other line and about the same width, making the ratio of length to width 2:46:1 or roughly, the length is 2.5 times the width. Family 13 and B have spleens very similar in shape and practically equal in length-width ratio which averages about 2:1. The spleens are 4 to 5 mm. shorter than in family 2 and about 1 mm. wider in the case of B. Family 35 has a very short spleen, averaging 22 mm. long. The ratio of length to width is 1.67:1. Crosses between families 2 and 13 have a family 13 type of spleen with the ratio of length to width slightly greater than in family 13, the ratio being for the crosses about 2.1:1. CP, the cross between family 13 and 35 has a spleen with a length-width ratio of 1.86:1, thus resembling more closely family 35. F_2 of this cross resembles 13 and B with a ratio of 2.02:1. C-O which includes mostly crosses between 2 and 35 has a spleen like the CY group with a ratio of 2.1:1. Similar results have been observed in swine killed at the abattoir at the Beltsville station.

Intestine Length Ratio

The ratio between length of small and large intestine is not as marked as the spleen ratios just described. Family 2 males have the lowest ratio of small to large intestine, the ratio being 1.36:1. The females of this family have a slightly larger ratio, 1.51:1. In groups 13, B and CP the ratio is nearly 1.5:1, while in the remaining groups, family 35, the CY groups and CP-1 and CO, the ratio is 1.4 to 1. The length and ratios of intestines are shown in Table XI.

Blood Calcium and Phosphorus

Calcium and phosphorus were determined in the serum by the methods of Clark and Collip, and Fiske and Subbarow respectively. Results showed great individual variation, especially in the phosphorus determinations. Some of the samples were too faintly colored to give a satisfactory reading. There seems to be no characteristic trend in any group, as the values seem quite variable between the groups. CY and CP have the highest phosphorus content, containing 4.9 mg. per 100 c.c. of blood. Family 13 and B have the lowest analysis with values of 3.65 and 3.68 respectively. The average phosphorus for all groups is 3.97 mg. per 100 c.c. blood. Calcium varies from 7.9 mg. per 100 c.c. in C-O to 11.6 in CP. Family 2 and B also have values above 11 mg. per 100 c.c. The average for all groups is 10.5 mg. per 100 c.c. The ratio of Ca:P in the different lines seems to be fairly constant. There is one notably low value, a ratio of 1.95:1 in C-O, and one high value 3.02:1 in B. The average for all groups is 2.64:1.

The results found agree fairly well with averages of 9-11.5 mg.

Ca and 2-5 mg. P as reported by Peters and Van Slyke (25), also the Ca value agrees well with that reported by Teich (28) which ranged from 6-13 mg. per 100 c.c. whole blood. The values for serum and whole blood are comparable for calcium, as most of the blood calcium is in the serum, but there is not agreement in the phosphorus, as most of the phosphorus is in the blood cells. Peters and VanSlyke state that an increase of Ca or P is accompanied by a decrease of the other constituent, which appears to be borne out by the ratios obtained in the data presented.

The coefficient of correlation was determined for Ca and P with a value of 0.43 which is only a fair correlation.

The amount of Ca and P was tabulated as to month in which the animal was killed to endeavor to ascertain if there might be a seasonal effect, but the numbers of animals were so few in some months, and an excess of animals of one group in some months make the result rather uncertain. Calcium values are highest from March to August, but differences in phosphorus values and ratios seem pretty well scattered throughout the year.

Data for calcium and phosphorus is shown in Table XII.

Catalase

The catalase determinations were made with the expectation of obtaining a measurement of the animals' activity. Koltzoff (16) reports finding three groups of guinea pigs with distinctly heritable different catalse content, and this was related to their vigor or activity. The present investigation fails to show any distinct differences in the several lines tested. According to the observed apparent activity, animals in family 35 are very excitable and active while in family 13 they are sluggish and not excitable. Thus one would expect a difference in catalase in these two groups, but the difference is only 2 c.c. greater of O_2 evolved in family 35 which can hardly be significant. The highest group is family 2 whose value expressed as c.c. of O_2 evolved is 84. Three other groups have values above 80 and no group is lower than 74 except CP-1 in which only 4 determinations were made. The average for the whole group is 78.8. Seasonal variation can not be satisfactorily determined because of the variability between individuals, groups and distribution of the groups through the year. The lowest values appear from June to September and the highest in November, December and January, possibly indicating greater activity of the animal during the cooler months.

Data for catalase determination is shown in Table XII.

Bone Measurements

Weight

The bones of the left fore and hind quarters were cleaned of the flesh by allowing the flesh to decompose for about 10 days, then boiling for about 8 to 10 minutes, after which time the flesh could be readily removed. The bones were allowed to air dry for about 2 weeks, then were weighed on a chemical balance. For the front quarter the bones weighed were scapula, humerus and ulna and radius, the latter two being weighed together. In the hind quarter the femur and tibia and fibula were

were weighed, again the latter two were weighed together. Bone weights are given in Table XIII.

There is considerable difference between the groups. Scapula weight in B and CP is considerably greater than in any of the other groups. Family 13, 35, CY and CY-2 vary only slightly from one another. Family 2 has the lightest scapula with C-1 only slightly heavier. Humerus weight follows in about the same order as scapula weights with B and CP the heaviest and family 2 and C-1 lightest. Family 35 and CY-1 are about equal, but the other groups show greater variation among themselves than is shown in scapula weight. Ulna and radius do not bear the same relation among the different groups as is shown by scapula and humerus. B and CP still hold to the highest weight groups, but family 35 is lightest with family 2 following in order. Family 13 and CP-1 form one weight group and the three in the CY group and C-1 form another group, slightly heavier than the former. In every case, the weight of the bones of the forearm of the cross-breds is heavier than in the corresponding bones of either parent family. The weight of femur shows almost the same relation between the groups as weight of ulna and radius with B and CP heaviest, and family 35 lightest. Family 2 is heavier than either family 13 or C-1. In femur weight, CY-2 and C-1 are lighter than the parent lines. The tibia and fibula of CP is slightly heavier than B. Family 35 is lightest and family 2 and 13 are very close inweight, slightly exceeding family 35. The bones of the cross-breds are in every case here heavier than the corresponding bones in the parent lines.

Only a few females entered into the calculations, but in every case the bones are considerably lighter than the corresponding bones of the male. The differences between male and female of each group are approximately of the same magnitude.

Coefficients of variability were not calculated for the individual bones but are given for the bones of front and hind quarters as groups respectively. The variation is not great in any line for either front or hind leg, and is practically equal for the total of all lines.

Length

The length of humerus, ulna, femur and tibia was measured with a calliper graduated to 0.001 inch. Measurement was made in each case of the greatest length of the bone in a line parallel to the long axis of the bone. The result of these measurements with standard deviation and coefficient of variability is given in Table XIII.

Family 13 has the shortest humerus and B the longest with family 35 and CP following. Family 2, CY-1 and CP-1 are practically equal. CP and B have the longest ulna with family 35 and CP-1 coming second. Family 13 and the CY group rank third in ulna length. C-O has the shortest ulna. The longest femur is in the B group with CP and CY second. Family 2 comes third and C-1 is the shortest. B, CP, C-O and CY have nearly equal tibia length. Family 2 is second. The shortest tibia length is shared by family 13, CY-1, CY-2, and CP-1. Tibia length seems to be more constant between the different groups than the other bones measured. There are 7 differences which are significant while for the other bones there are 11 to 15 significant differences, but these are scattered and not confined to any particular groups with the exception of humerus measurement which in family 2 differs significantly from most of the other groups. The coefficients of variability are extremely small for all bones in every group. In every case except CP-1 the bones of the female are shorter than those of the male. The exception in CP-1 is probably due to the fact that only one female was measured. Significant differences of bone length between the different groups are given in Table XIV.

Correlations

Coefficients of correlation were calculated for bone length in families 2, 13 and B with the result that all were high except the one between ulna and femur in family 2, with a value of 0.454. All other correlations are 0.67 or above. In family 2 the highest correlation is between ulna and tibia length. In family 13 the highest correlation is between humerus and tibia. Correlations in family 13 have a tendency to be higher than those in family 2. The highest correlation in B is between femur and tibia with a value of 0.901. Correlations in B average higher than in family 13. These correlation values are given in Table XV. The values of these correlations agree well with those of MacDowell (21) for rabbits and those of Dunn (4) for inbred White Leghorn hens.

Fat Color

After several animals had been studied, it was noticed that one of a different group had almost chalky white fat. After this, record was kept of fat color in all animals studied. In checking over the results of the observations, it is probable that all but 4 or 5 of the 46 animals, killed before note was made of fat color, had yellow fat.

These 4 or 5 exceptions were probably cream colored rather than white if they are in keeping with the remainder of the groups to which they belonged.

Of the 53 animals observed in family 2 all but one were graded yellow or light yellow. This exception was graded light cream. In groups 2, 13 and B there was a range of fat color from light yellow, through cream, light cream, very light cream, and white in B. None in 13 and 35 were called white, but in several instances a note read "practically white," indicating that there was only a slight suggestion of pigment. In the CY and C-O groups the observations were about equally divided between the lighter and darker grades of yellow, while in the CP group the tendency was towards the lighter grades, but none were graded as white. A summary of fat color observations is shown in Table XVI. This condition is similar to that reported by Pease (24) for rabbits. Whether it is due to a single gene is not yet definite. It may be supposed, however, that white is dominant and may be represented by YY in its homozygous form. Y_y would be intermediate between white and the recessive yellow, yy. The data as found agree very well with this hypothesis, but a difficulty presents itself in explaining the heterozygous condition which must exist in families 13 and 35 according to this hypothesis, since these families have been inbred for 30 generations by brother-sister matings. Crosses have been made between family 2 and B for further study of this character.

Review of literature and comparison with present experimental data

There has accumulated during the past 25 years much literature related in one respect or another to the present investigation. Joseph (15) has investigated the ratio between heart weight and body weight in various animals. For the guinea pigs he gives 4.22 gm. and 3.91 gm. per kilogram of body weight for males and females respectively. These values were derived from scarcely half grown animals, however, as the live weights were given as 384 and 257 grams respectively. Unless the rate of heart growth is the same as general body growth, the values given would not necessarily hold for more mature animals. In none of the groups studied in the present investigation did the percentage of heart weight of live weight reach these values, the average for all groups being approximately 2.8 gm. per kg. body weight. Hatai (12) has presented data on the weight of some of the ductless glands of the Norway and albino rat according to sex. His data show that there is considerable difference between the two varieties except in thyroid weight. The suprarenals and pituitary are larger in the females of both varieties. In the guinea pig data presented in this paper all of the ductless glands studied are heavier in the female than in the male in family 2. There are so few females in the other lines studied that nothing definite can be stated in regard to this relationship.

Jackson (14) has made a study of the variability of body and various organs of the albino rat at various ages from birth to 1 year of age. He finds that the various organs can be grouped as to amount of variability. In the slightly variable group are head and head organs with coefficients of variability ranging from 10 to 12 percent. In the moderately variable group are heart, lungs, liver, suprarenals and kidneys with coefficients of variability ranging from 21 to 26 percent. In the extremely variable group are thymus, spleen, gonads, and intestinal canal whose coefficients of variability are above 29 percent. The coefficients of variability are less if the weights are expressed as percentage of live weight than when expressed in actual weight. The highest correlations with body weight are weight of kidneys, liver and lungs with correlation coefficients of 0.80 to 0.86. Brain, heart and gonads come next in rank with correlation values of 0.75 to 0.78 while the remainder of the organs had correlation values of 0.40 to 0.45 with live weight. Very few of the guinea pig organs fell in the same grouping. Eyes fell in the group of low variability, liver in the medium group, and spleen in the highly variable group. All the other organs or glands fall into quite different groupings than that shown by the rat data. The highest variability shown in the guinea pig data falls in the range of medium variability as shown by Jackson, showing that the guinea pig material was less variable than the rats. In only about half of the measurements in the guinea pig data are the coefficients of variability smaller when expressed as percentage of live weight. The highest coefficient of correlation which was consistent in the three groups studied was that of heart weight with live weight. Certain other organs showed higher correlations, but these were not consistent in the different groups.

Donaldson (3) has assembled a vast amount of data on various studies with rats, some of which is included in references already cited. He points out that the weight of some organs follows age more closely than it does body weight. Such an organ is the eye. In family 2 of the guinea pig data in this paper, correlations between age and weight of the organs are greater in every instance except that of the liver, than correlation of these organs with live weight. However, in family 13 and in B the correlation between live weight and the organs tends to be greater than age-organ weight correlations. The eye is a notable exception in these two groups.

Bessessen and Carlson (1) have made a study of the post-natal growth of the body and organs of the guinea pig. Only 82 animals were used and the material ranged in development from birth to maturity. The main point brought out in this work is the growth curves of the various organs. Due to the different character of the growth curves of some of the organs from the growth curve of the animal as a whole, differences in the relation of organ weight to live weight will vary at different periods of development. Comparison of organ weights for certain live weight agrees very well with the data presented in the present paper.

Swett, Graves and Miller (27) have made anatomical and skeletal comparison of a highly specialized dairy cow and a highly specialized beef cow. The live weight of the latter was approximately 1.66 times that of the dairy cow. The beef cow had a high finish while the dairy cow had only a slight deposit of fat. In general body height the beef cow was slightly smaller than the dairy cow. The body volume of the beef cow was nearly 70 percent greater than that of the dairy animal. The weight of organs or parts per 100 pounds of empty body weight was much lower for the beef animal than for the dairy animal. Kidney weight and adrenal weight were distinctly greater for the beef animal, while spleen weight was almost equal in both. The length of intestines was about 15 feet greater in the beef animal. The difference in heart weight between the two animals was negligible. In general the organs of the beef animal were the larger. In skeletal measurements, the leg bones were shorter in the beef animal and distinctly heavier. Considering the two animals as a whole, the main difference was in external form.

Family 2 on the one hand and family 13 and B on the other may be considered as corresponding in type to the dairy and beef animals respectively, at least when weight is considered. In actual weight of organs, family 13 and B are greater than family 2 in every case except spleen and adrenal weight while on a percentage of live weight basis, family 2 exceeds by significant differences the other two groups in all but thyroid weight. This latter comparison corresponds to weight of organs per 100 pounds empty carcassweight in the cows. Bone length measurements are greater in B than in family 2 in the four bones measured, but this does not hold in family 13 where only ulna is greater than in family 2. Bone weight is greater in B than in family 2 in all weights taken, but family 2 exceeds family 13 in weight of humerus and tibia and fibula. It appears that there is greater skeletal difference in the leg bones of guinea pigs of two lines differing greatly in live weight than there is between a beef and a dairy animal.

Schmidt and Vogel (26) have made measurements of the heart, liver, kidneys and spleen of swine slaughtered at about 105 kg. live weight. Nearly equal numbers of both sexes were used. The organ weights of the males were slightly greater than those of the females except kidney weight, but this difference was not significant. The coefficients of variability were greater in the females. There was an appreciable correlation between weights of all organs.

Hammond (11) has made extensive studies of a similar nature with sheep. The relation of the different organs to breed and to one another is discussed. Factors influencing skeletal growth and correlations between the different parts are given. Unfortunately this work was not available, so that comparisons could not be made between sheep data and the guinea pig data of the present work.

Freudenberger (10) has compared the Wistar albino and the Long-Evans hybrid strain of the Norway rat. In all measurements except weight of brain, eyeballs and thymus, the Long-Evans hybrids exceed the Wistar albino strain. There were no consistent sex differences. In the Wistar strain the brain, spinal cord and eyeballs form a group of low variability (coefficients 5-8); suprarenal glands, stomach, intestines, submaxillary glands, liver kidneys, heart, lungs and ovaries form a group of moderate variability (coefficients 13-20); and hypophysis, thyroid, thymus, spleen and uterus form the most variable group (coefficients 20-26). There are no consistent differences in coefficients of variation between the sexes of the two strains. The variability is much lower than that found by Jackson (14). The magnitude of variability agrees quite closely with the variability found in the guinea pigs studied, but only thyroids, spleen and liver fall in the same groups as determined by degree of variability.

Discussion

Anatomical and Physiological Aspects

That the various lines studied clearly differ from one another in general body size is evident from comparison of the live weights, and has been recognized in various publications (31, 34, 7) as one of the outstanding characteristics of the different families. These differences were evident from the early history of the inbred lines, and have persisted and probably been intensified by the more than 25 years of inbreeding which the stock has undergone. The differences between the various lines at birth are not so great, but differences in growth rate and duration of the growth period account largely for differences in mature weight.

In the present analysis of organ and gland weights and various parts of the carcass, the various families also show similar differences. Thus the heavy lines, as family 13 and B and the crossbred line CP have heavier front and hind quarters and loin than the lighter lines, such as family 2 and the CY group of crossbred animals. Similarly, heart, lungs, liver and other organs are larger in the lines with heavy live weight than in those which are smaller. When, however, the weight of these organs or glands and other parts of the carcass are expressed as a percentage of the live weight of the animal, many of the differences between the various lines disappear, showing that the weight of most of these separate parts of the carcass bear a certain proportion to the carcass as a whole, or in other words, there is an equilibrium or balance between the various parts which go to make up the animal body as a unit.

Thus the heavier organs of the heavy families are heavy because of the larger unit of which they form a proportionate part, but which proportion is practically the same whether the animal is large or small. There may be a certain source of error in expressing weight of the various parts as a percentage of live weight, since several factors may affect live weight without materially affecting the weight of the organs. Thus one animal might be heavy and coarse of bone yet sparely fleshed and lacking in fat, while another might be finer and lighter boned, but in a high condition of fleshing and finish. There would hardly be a fair comparison between two such animals. Or two other animals may be very similar as to skeletal proportions and muscle, but one may have a tendency to put on fat while the other lacks this tendency. The proportion of parts to the whole would appear smaller in the fat animal than in the spare one, unless the accumulation of fat were distributed equally in the organs and muscle layers of the body. The condition actually observed in the animals dealt with in this report is that family 13, B and CP appear to have a tendency to lay on fat more than family 2 and the CY group of crossbreds, though no analyses have been made to confirm this. Other conditions as moisture and mineral content of the muscles and organs of the body could appreciably affect the ratio of parts to live weight. Further study is in progress at the present time to clear up some of these points.

But whether or not there is an error in expressing the weight of parts in proportion to live weight, it would be expected that most of the organs, except possibly liver, which is capable of storing up considerable fatty tissue, would show the same error. Yet there are a few organs or glands in some of the groups which show wide departure from the general relations of the other organs of that group to other groups. The most notable exception is in family 2 in which heart, eyes, kidneys, spleen, adrenals and pituitary bear a higher ratio to live weight than in any of the other groups, yet the quarters, loin, lungs, liver, thyroid and testicles are about the same proportion to live weight as these parts are in other groups. In fact, thyroid and testicles are much smaller in family 2 than in several of the others. Not only are spleen and adrenal proportionately larger in family 2, but in actual weight are exceeded only by C-0, except spleen weight in C-1 which is based on only 2 observations.

On the other hand, B the heaviest group in live weight, has the smallest actual and percentage weight of adrenal. Elliott and Tuckett (8) found about the same value for the adrenal gland expressed as percentage of live weight. They state that the guinea pig has relatively the largest suprarenal gland of any animal. The size is due to exaggerated growth of cortex. The medulla attains its full development by the end of the first month, but the cortex continues to grow in close parallelism with the animal's weight. They note, however, that there is a real difference in adrenal weight between different breeds of guinea pigs. Watson (29) in studies with wild and tame rats finds the adrenal gland of the wild rat more than twice as large as that of the tame rat. He explains this as probably due to greater muscular activity of the wild rat. This can hardly account for difference of size of adrenal in the lines of guinea pigs studied. All lines are from stock long domesticated. Family 35 appears to be more active than the other lines, yet this has an adrenal among the smallest in size. There seems to be a difference in the firmness of flesh between some of the different lines. For examples family 35 and CP seem hard and firm with a sort of tensity or rigidity of muscle while family 13 seems flabby and soft. B is harder than family 13 but not as hard as 35 or CP. No measurements have been made of these qualities, but they are very apparent to one who is familiar with the various groups. It is possible that this difference of muscle tone is related to the adrenal glands, but if so, weight of gland must not be associated with activity.

Just what the difference of spleen shape and spleen weight may indicate is not clear at this time. Size of animal apparently has no relation to spleen weight, for the heaviest families have the lightest spleens and the lightest family has by far the heaviest. A long spleen is found in both light and heavy lines. The CP groups which contain blood of family 35 have a spleen similar in shape to that of family 35.

Neither is pituitary gland in several instances in keeping with live weight if pituitary activity is related to pituitary weight.

Length of small intestines seems rather consistent with live weight in that the heaviest animals have the longest small intestine. This is probably the means of giving increased surface for absorption of food to the larger animals. The length of large intestine does not appear to be so closely related to the weight of the animal. It is interesting to note that total intestine length of families 2, 13 and 35 varies only 5 cm. in length, and that family 13, the heaviest family of these three, has the shortest total intestine length. B and CP, both heavy groups, have total intestine length approximately 20 and 10 cm. greater than that of the three groups previously named. While most of the absorption of food materials takes place in the small intestine, yet the similarity of total intestine length in families 2, 13 and 35, with the great difference in live weight of these three groups, suggests the possibility of a difference of metabolic efficiency between them.

Bone measurements show some interesting relationships. In the heavy lines bone forms about 6.7 percent of the total weight of both front and hind quarters, and in the light lines approximately 7.5 percent. Thus it appears that either the bones are smaller in the large animals or there is better fleshing. In scapula weight B and CP are the largest and differ from one another by only 0.1 mg. in weight. On the other hand, family 2 and C-1 have the smallest scapulas, averaging 0.1 gm. lighter than those of B and CP. The CY groups have a scapula weight approximately like that of family 13 namely, 0.55 gm. Scapulas of family 35, CP-1 and C-0 range from .57 to .60 gm. weight. Humerus weight does not follow in the same order as scapula weight. B and CP are heaviest, but family 13 and C-1 are lightest. Family 2 humerus is heavier than that of family 13 and the CY group are heavier than family 2. Families 35 and 2 have the lightest ulna and radius while B and CP still hold to the heaviest. Ulna and radius weight of family 13 is lower than that in the CY groups. Similarly the bones of the hind leg show differences of relationship. The only consistency in bone weight relationship therefore seems to be that B and CP have the heaviest in all bones weighed. This must indicate then that there is better fleshing on the quarters of these two heavy groups than in the lighter groups, since the bones, while actually heavier, form a lower proportion of the total quarter weight, than in the light weight groups.

All bones measured are longer in group B than in the other groups. This undoubtedly accounts for their greater weight. The bones of family 2 are longer than those of several other groups, likewise accounting for the fact that family 2 does not have the lightest bones in every case. Correlations were calculated between bone length and weight for humerus and femur in families 2, 13 and B which show that humerus weight is about 60 percent dependent on length and femur weight about 30 percent dependent on length. B is not consistent with family 2 and 13 correlations, as humerus has a lower length-weight correlation and femur a higher one than these two groups. The value of these correlations is shown in Table XVII.

TABLE XVII. Correlation of length and weight of humerus and femur in families 2, 13 and B.

Group	Humerus	Femur
Family 2	.764	.545
13	.768	.599
B	.618	.802

In every case where measurements were available on the bones of females, they were somewhat lighter in weight and of smaller dimensions than the bones of males. This is consistent with the condition in most animals.

The blood analyses showed a great individual variation and considerable variation between the groups. This possibly may be accounted for. Meigs et al. (23) working with dairy cattle point out that differences in the quality of hay and conditions during the period of curing affect the assimilation of calcium by the animal and disturb the calcium-phosphorus ratio. Health conditions of the animals also affect the assimilation of calcium. Whether these same factors hold true with guinea pigs has not been determined. The quality of hay and greens fed was extremely variable. In winter cabbage and kale are fed which often becomes very inferior in quality in the spring before fresh greens can be cut. Green feed through the growing season of the year consists of rye and green alfalfa. The animals appear more healthy with this feed than through the winter. However, no animals which appeared to be in any way in an unhealthy condition were used in this study. The fact that only a few animals were killed at a time and that the study extended through nearly two years gives ample chance for variation as a result of the conditions named above.

In interpreting the high or low calcium and phosphorus values, little can be said regarding the relation of these values to vigor, but the ratio between these constituents may give a slight indication of vigor. At the time the studies were made and for some time previous and since, family 13 has been the most vigorous as measured by fertility and low mortality. B and family 2 rank next in order, except possibly some of the crossbred lines. The ratio of Ca to P in the more vigorous lines has a tendency to be higher than in the less vigorous lines. Yet in CP and CY crosses, both of which are vigorous, the ratio of Ca to P is low.

The catalase determinations also do not give much indication of the vigor or activity of the animals. Family 35 which appears to be much more active than the others would be expected to have a higher catalase content, but four other groups show higher values. The heavier groups which might be expected to be less active have lower catalase content than some of the others. General health of the animals and season of the year possibly may affect the catalase values. The author feels that further investigations should be attempted in determining the relation of blood catalase to the vigor of the animal.

Age effects, while present, probably account for but little of the variation found within the groups and between the groups. Very old animals, several of which occurred in family 2, may have affected some of the weights and ratios to some extent. There were only a few such animals in the other groups. More mature animals and less range in age at slaughter would probably give more uniform results than are found in the present data.

Genetic Aspect

The differences of size and various other characteristics in the inbred lines of guinea pigs have been considered in previous studies (22, 6) as due in part to genetic causes. Two of the inbred lines of this study (families 2 and 13) are clearly different in size. Both of these differ from family 35 in color which is due to a single gene (C in families 2 and 13 and c^k in family 35). There is enough consistency in the weight, mortality and litter size of these families to regard them as genetically different. In crosses between the different families there are certain differences, but not great enough to consider them as a segregation of factors having to do with size or vigor. This suggests that there must be a great complexity of the genetic factors which control size and vigor.

The system of mating employed, namely brother-sister matings, and the number of generations through which it has been practiced, namely at least 28 generations in family 2, more than this in families 13 and 35, should give the animals an extremely high percentage of homozygosity. Yet when one observes the variation in some of the inbred lines, there still appears to be a considerable percentage of heterozygous characters present. If this is the condition, explanation is necessary to account for it after such intensive and prolonged inbreeding. Let it be assumed that at the beginning of the experiment the foundation stock was heterozygous for several genes which determined size. The genes in the stock forming family 2 might have been different from those in the stocks from which families 13 and 35 descended, thus giving them differences of size and other characters which have been used as measure of vigor. Continued inbreeding would gradually make the various lines more homozygous for those characters, and thus "fix" certain body size and proportions for a particular family. Let it be assumed also that certain other genes had an effect on certain unknown physiological processes which determined whether an animal should have enough vitaility to develop into an individual capable of reproducing itself. Let us assume that vigor is dependent on a heterozygous combination of genes. As a higher percentage of homozygosis is reached, the ability of the stock to survive and reproduce becomes lessened. Thus the more homozygous groups will gradually die out while the heterozygous groups will continue to perpetuate the line. Some observations within the different families tend to confirm these assumptions. Family 13 has been carried through 33 generations of brother-sister mating. This family has been one of the most vigorous throughout its history, and for the past three or four years has been the most vigorous. Early in the history of this family a defect of head development, known as otocephaly, appeared. These abnormal animals are dead at birth, but well developed except for the head region. Evidence cited by Wright and Eaton (33) shows that this defect is hereditary and probably is influenced by some environmental factors acting at a certain period of early embryonic development. The percentage of this defect has gradually increased in certain sub-lines until in the nineteenth generation a line developed which produced 21.5 percent of monsters and later increased to about 34 percent. This line has died out in the Bureau of Animal Industry stock but Wright (35) reports that in the Chicago branch of this same family the percentage is about 27 but tends to relapse to 5 percent. While the details of gene combination as explained by Wright are not the same as proposed at the beginning of this paragraph, the principle that certain sub-groups gradually eliminate themselves while others persist remains essentially the same. A study of the pedigree chart of any of the inbred lines shows that certain sub-lines split off and continue for a few generations, while others persist and form the main group of the family. Since the matings are made at random from the original record sheets, it can not be selection from certain groups that perpetuates them at the expense of the others, but simply the operation of nature in eliminating the less vigorous groups.

The coefficients of variation of the groups show that most of the lines are about equally variable, indicating that all are probably about equal in percentage of homozygosis or heterozygosis. B, which should theoretically be most variable, is less variable than family 13 when the variability of all measurements are calculated together. The most outstanding observation on variability is that family 35 is lowest with the exception of C-1 which is based on only 2 observations. Does this indicate that family 35 is more homozygous than the other inbred groups? If so, it is in keeping with the suggestion of the previous paragraph, that as homozygosis increases, vigor decreases. Family 35 is one of the lines that has been most difficult to maintain. In size it is intermediate between families 2 and 13, but other measures of vigor, as mortality, show that it is inferior to these two families. Under unfavorable weather or food conditions, family 35 experiences the greatest ill effects. The small variability among the various groups, including the control stock B which should theoretically be more variable than the others, is probably explained by the small number of observations for the several groups. In a previous study (22) it was found that inbreeding decreased variability by about 40 percent.

The variability of the different body parts yields interesting data. Parts like the front and hind quarters and loin have about the same variability as live weight, but the organs and glands show greater differences, some having a high degree of variability while others are low. Intestine length, and weight of kidneys and eyes show lowest variability. Weight of lungs, thyroid and adrenal glands show the highest. Function of the organ in some cases might explain this difference in variability. For example, the eye would not need to vary to as great a degree with certain variations in live weight to function efficiently as would an organ like the heart or digestive organs, upon whose capacity to function properly the well being of the whole organism depends. But kidney weight and intestine length under this theory should be more variable than they are. Adrenal weight variation may be attributed to the large amount of cortex, but pituitary and thyroid weight can not be accounted for in this manner. The data presented fails to show much relationship between efficiency of these glands and weight. The bone measurements showed small variation. From these differences it appears that extreme variation in some parts is balanced by low variation in others, so that the variability of the organism as a unit is but slightly affected. The data on rats presented by Jackson (14) showed greater variability in all measurements than is shown by the guinea pig data presented.

It can not be proved from the data presented that there are special genes in any of the families which determine the size of any special organ or set of organs. There are a few cases, however, which suggest special genes. One of these is spleen shape and size in familes 2 and 35. Crosses in which family 2 occurs tend to have the long type of spleen while those crosses in which family 35 is a parent have the short stubby type of spleen. Not enough crosses between 2 and 35 have been studied to determine the relation of spleen inheritance in this combination.

The inheritance of large adrenal cortex in family 2 giving it a weight greater than in any of the other lines, and in contrast, the small adrenal of B appears to be due to special genes affecting this gland. The other cases of larger eyes, kidneys and pituitary in family 2 may be only apparent because of the small live weight of this line. The generally low correlations between live weight and weight of some of the organs may indicate that some factors other than the ones affecting size in general are acting upon these organs, or that general size factors do not act in the same degree on all parts of the organism.

Practical Applications

Among our various classes of livestock one finds wide variation in adherence to type, fleshing and fattening qualities, tenderness of meat, and other characters which determine the economic value of the animals concerned. That some of this variation can be bred out by careful selection is beyond question, but to what degree it can be eliminated is one of our greatest concerns of the present day. There are herds which generally appear uniform, and theoretically because of carefully selected ancestry should be, but still they show considerable variation in rate of gain, in slaughter age, in finish after slaughtering, and even in cooking tests. Just why this variation persists has not been completely and satisfactorily determined. All variation can not be considered genetic, and therefore a certain amount should always be expected to be present in any herd or flock. Just when the point is attained when genetic variation ceases and only non-genetic variation exists is apparently difficult to determine. Whether such a condition can be reached without a long period of close inbreeding and rigid selection without in some other ways affecting the vigor and economic value of the animals is still to be determined. We can only look forward to this goal and apply such practices and principles as seem to enable us to attain it and still be consistent with practical animal breeding and production for economic purposes.

If we seek to lay especial emphasis upon a particular part or quality in an animal's development, there will probably be a change in some other part to preserve the balance, and this change may be of such a nature as to be detrimental rather than beneficial. Thus, persistent selection for minimum bone in beef animals might result in actually decreasing the animal's size. Overfattening qualities in swine might interfere with their reproductive capacity. Breeding for maximum wool production in sheep might interfere with the ability of the animal to do well in damp climates or to graze efficiently in rough regions with scanty pasture.

The fact that herds or flocks which have been carefully bred and selected show great uniformity proves that much of the variation found in mixed herds can be eliminated by the use of more highly bred animals. Future improvement depends upon continued use and application of the principles of genetics and judicious selection from animals which have proved their ability to produce uniform and vigorous offspring, or in other words, those which contain the "superior germ plasm."

Summary and Conclusions

Data are presented on the weights of organs and glands and on analysis of certain constituents of the blood of inbred and cross-bred groups of guinea pigs.

These groups differ in live weight and in weight of body organs and glands. However, when the weight of organs or glands is expressed as percentage of live weight many of the differences disappear, showing that a certain balance exists between the animal as a whole and its various parts.

Family 2 which was analyzed more in detail than the other groups revealed that age differences beyond certain limits influence the size and proportion of the various organs.

The variability of all groups was about equal with the exception of family 35 which shows lower variability than the other lines.

The various organs differ in variability. In general, lungs, thyroid, spleen and adrenals show high variability. Hind and front quarters, eyes, kidneys and length of intestines show low variability. The variability of the other organs studied falls between these groupings.

Coefficients of correlation between live weight and weight of individual organs do not show high values. Coefficients of correlation between the different organs do not show high values. These results show that factors other than genetic must have considerable influence on the size of body parts.

Bone forms about 6 percent of the weight of front quarter and about 7 percent of the weight of hind quarter in all groups.

There is a tendency to a higher percentage of bone to meat in the lighter groups.

Bone weight and length of front and hind quarters shows low variability.

Bone weight is 30 to 40 percent dependent upon length.

Calcium and phosphorus of the blood serum show great individual variation, but between the different groups the variation is small. There is a tendency for calcium and phosphorus values and ratios to be higher through the warm seasons of the year when better quality feed is available.

Catalase content of the blood shows little variation between the different lines. There seems to be a tendency toward higher values in the cool months of the year.

The ratio of length of small to large intestines is fairly constant.

The ratio of spleen length to width varies markedly between families 2 and 35, the former having a spleen length of about 2.5 times its width, while the latter is about 1.6 times its width. Each type appears to be inherited in crosses. Other groups have a spleen whose length is approximately twice its width.

A difference in fat color was noted between family 2 and B and some of the other lines. Family 2 consistently has a yellower fat than the other groups, while in several of the B animals the fat was almost chalky white, and in all the B animals much lighter than in any of the other groups. Fat color in the other groups appears to be intermediate between that of family 2 and B, but in crosses involving family 2 there is a tendency toward the darker yellow color.

There is not much evidence for special genetic factors influencing the shape or size of special organs unless it is in the shape of spleen and size of adrenal glands.

The breeding of animals for emphasizing special physical development can probably not be accomplished without effecting certain changes in other parts which seem to be the result of a balancing reaction.

Breeding for animals well proportioned and developed in every anatomical and physiological relation should be practiced, rather than over emphasis for some specialized character which in the end may prove detrimental to the general economic value of the animal rather than beneficial.

Future livestock improvement must depend upon employing the principles of genetics along with judicious selection of breeding stock from sires and dams which have been proved as to uniformity of performance in producing uniform and vigorous offspring.

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TABLE II. Measurement of parts in groups of inbred and crossbred guinea pigs, expressed as percentage of live weight.

Measurement Concerned	Statistic*	Experimental Group: Family 2	Family 13	Family 35	Control B	C-0	C-1	CY	CY-1	CY-2	CP	CP-1	Average
Weight of Front Quarters	M	7.07	6.71	6.69	6.79	7.21	7.20	7.15	6.92	7.03	6.83	6.78	
	σ	.339	.418	.477	.634	.546	.100	.380	.359	.631	.482	.358	
	C.V.	4.79	6.23	7.13	9.34	7.57	1.39	5.31	5.19	8.98	7.06	5.28	6.38
Weight of Hind Quarters	M	8.86	8.29	8.38	8.20	8.67	8.91	8.91	8.64	8.93	8.65	8.31	
	σ	.494	.584	.462	.593	.547	.000	.337	.478	.436	.488	.526	
	C.V.	5.58	7.04	5.51	7.23	6.31	.000	3.78	5.53	4.88	5.64	6.33	5.94
Weight of Loin	M	6.77	6.77	6.91	6.73	7.13	7.19	6.92	7.05	6.95	7.08	6.78	
	σ	.554	.667	.504	.620	.560	.180	.491	.372	.392	.577	.543	
	C.V.	8.18	9.85	7.29	9.21	7.85	2.50	7.10	5.28	5.64	8.15	8.01	8.01
Weight of Heart	M	.300	.261	.270	.248	.261	.312	.290	.295	.283	.262	.278	
	σ	.040	.035	.022	.011	.019	.027	.020	.028	.024	.027	.044	
	C.V.	13.37	13.49	8.04	4.52	7.13	8.65	7.03	9.42	8.66	10.38	15.94	10.31
Weight of Lungs	M	.671	.605	.613	.605	.599	.706	.637	.710	.616	.632	.840	
	σ	.168	.099	.094	.157	.069	.161	.150	.178	.091	.152	.239	
	C.V.	25.04	16.38	15.33	25.97	11.65	22.88	23.61	25.08	14.71	24.07	28.43	21.93
Weight of Liver	M	3.478	3.239	3.106	3.004	3.036	3.337	3.331	3.374	3.277	3.056	3.609	
	σ	.572	.448	.270	.236	.371	.418	.380	.507	.454	.345	.318	
	C.V.	16.46	13.84	8.70	7.85	12.22	12.54	11.41	15.04	13.86	11.30	8.81	13.05
Weight of Kidneys	M	.799	.563	.649	.567	.661	.741	.680	.670	.641	.574	.652	
	σ	.094	.073	.102	.068	.081	.105	.064	.064	.046	.066	.105	
	C.V.	11.78	12.95	15.65	11.96	12.19	14.17	9.46	9.61	7.24	11.57	16.10	11.86
Weight of Spleen	M	.1154	.0838	.0833	.0758	.0973	.1176	.1019	.0936	.0853	.0736	.0753	
	σ	.0175	.0161	.0140	.0186	.0122	.0120	.0165	.0164	.0133	.0137	.0134	
	C.V.	15.16	19.21	16.81	24.54	12.54	10.20	16.19	17.52	15.59	18.61	17.80	17.54
Weight of Eyes	M	.1842	.1530	.1707	.1321	.1590	.2367	.1719	.1797	.1692	.1498	.1635	
	σ	.0175	.0165	.0135	.0125	.0188	.0781	.0208	.0355	.0184	.0123	.0345	
	C.V.	9.50	10.78	7.91	9.47	11.82	33.00	12.10	19.76	10.87	8.21	21.10	11.26
Weight of Pituitary	M	.0024	.0020	.0015	.0022	.0019	.0022	.0023	.0022	.0021	.0018	.0020	
	σ	.00026	.00038	.00037	.00045	.00035	.00014	.00022	.00050	.00029	.00029	.00051	
	C.V.	10.83	19.10	25.34	20.64	18.72	6.31	9.61	23.15	13.74	15.93	25.37	16.68
Weight of Thyroid	M	.0139	.0148	.0142	.0118	.0135	.0138	.0136	.0146	.0121	.0141	.0158	
	σ	.00255	.00268	.00139	.00281	.00182	.00045	.00239	.00470	.00265	.00174	.00371	
	C.V.	18.35	18.11	9.79	23.81	13.48	3.26	17.57	32.19	21.90	12.34	23.48	19.35
Weight of Adrenals	M	.1279	.0805	.0889	.0657	.1161	.1004	.1041	.0952	.0941	.0860	.0995	
	σ	.0248	.0244	.0165	.0206	.0219	.0145	.0250	.0177	.0195	.0251	.0280	
	C.V.	19.39	30.31	18.56	31.35	18.86	14.44	24.02	18.59	20.72	29.19	28.14	23.46
Weight of Testicles	M	.560	.553	.642	.554	.627	.742	.601	.631	.622	.623	.629	
	σ	.1018	.0538	.0612	.0686	.0690	.1275	.1172	.0818	.0718	.0568	.1223	
	C.V.	18.18	9.73	9.53	12.38	11.00	17.18	19.50	12.96	11.54	9.12	19.44	13.98
Average C.V. for Group		13.59	14.39	11.97	15.25	11.64	11.27	12.82	15.33	12.18	13.20	17.25	

* M - Mean; σ - Standard Deviation; C.V. - Coefficient of Variability.

TABLE III. Significance of differences between inbred and crossbred groups of guinea pigs.
(Asterisk at left signifies significant differences between actual measurements, at right between percentage measurements)

Groups	Live † Weight	Front Quarters		Hind Quarters		Loin		Heart		Lungs		Liver		Kidneys		Spleen		Eyes		Pituitary		Thyroid		Adrenals		Testicles		Small † Intestine	Large † Intestine	$N_1 + N_2$
2 and 13	*	*	*	*	*	*		*	*	*	*	*	*	*	*		*	*	*	*	*	*		*	*	*		*	*	98
35	*	*	*	*	*	*		*	*	*		*	*		*		*	*	*	*	*	*		*	*	*	*			82
B	*	*	*	*	*	*		*	*	*		*	*	*	*		*	*	*	*	*	*		*	*	*		*	*	102
CY	*	*		*		*									*		*			*					*	*				77
CY-1	*	*		*		*	*	*		*		*			*		*	*			*	*		*	*	*	*			87
CY-2	*	*		*		*								*	*	*	*		*		*			*	*	*				79
CP	*	*	*	*		*		*	*	*		*	*		*		*	*	*		*	*			*	*		*		78
CP-1	*	*		*	*	*		*		*	*	*			*	*	*	*	*		*	*			*	*				74
C-O	*	*		*		*	*	*	*			*	*		*		*	*	*		*	*		*		*	*	*		83
13 and 35														*	*			*	*	*	*					*	*		*	42
B	*	*		*		*			*	*			*	*					*	*			*		*	*		*	*	62
CY	*	*	*		*	*			*	*		*			*		*		*		*	*			*	*			*	37
CY-1	*	*		*	*	*			*		*				*		*		*						*		*			47
CY-2	*	*			*	*			*	*		*			*	*		*	*			*	*				*			39
CP				*										*												*	*		*	38
CP-1										*	*			*	*												*			34
C-O			*									*		*	*	*	*			*				*	*		*		*	43
35 and B	*	*		*		*			*			*			*			*	*	*	*		*		*		*	*		46
CY	*	*	*		*	*		*	*					*			*	*		*	*	*				*				21
CY-1	*	*		*		*			*					*			*			*	*					*				31
CY-2	*	*			*	*				*				*				*		*	*	*	*			*			*	23
CP	*	*		*		*		*											*	*	*									22
CP-1										*	*	*	*							*	*							*		18
C-O			*													*	*	*		*	*			*	*					27
B and CY	*	*		*	*	*		*	*	*		*	*	*	*		*		*	*					*	*		*		41
CY-1	*	*		*	*	*	*	*	*		*	*	*	*	*		*		*	*			*		*	*	*	*	*	51
CY-2	*	*		*	*	*		*	*	*		*	*	*	*	*			*	*		*			*	*	*	*	*	43
CP					*				*									*	*	*	*		*	*	*		*			42
CP-1	*	*		*		*			*		*		*		*			*	*	*			*		*		*	*		38
C-O	*	*	*	*	*	*		*	*	*		*			*		*		*	*	*		*	*	*		*	*		47
CY and CY-1																														26
CY-2																*	*												*	18
CP	*	*		*		*		*	*			*			*		*	*	*		*	*				*				17
CP-1					*					*		*					*					*								13
C-O	*	*				*			*					*							*			*		*				22
CY-1 & CY-2																														28
CP	*	*		*		*		*	*						*		*		*		*					*		*		27
CP-1										*							*									*				23
C-O	*	*		*		*			*		*		*	*		*								*	*	*		*	*	32
CY-2 and CP	*	*		*		*		*		*				*	*			*	*			*				*		*		19
CP-1					*					*	*	*		*				*				*	*							15
C-O		*				*			*					*		*	*					*		*	*	*		*	*	24
CP and CP-1				*									*																	14
C-O	*			*		*		*							*	*	*	*				*			*	*				23
CP-1 and C-O										*	*	*	*			*	*	*				*								19

TABLE IV (a). Rank of variability of measurements in groups of guinea pigs, and rank of groups.

Degree of Variability	Measurements Concerned	
	Actual Weight Basis	Percentage of Live Weight Basis
High Variability	Adrenals Thyroid Lungs Spleen	Adrenals Lungs Thyroid Spleen Pituitary
Medium Variability	Liver Pituitary Loin Testicles Heart	Testicles Liver Kidneys Eyes Heart
Low Variability	Live Weight Front Quarters Kidneys Hind Quarters Eyes Large Intestines Small Intestines	Loin Front Quarter Hind Quarter

TABLE IV (b). Rank of Groups, Low to High

	Actual Weight Basis	Percentage of Live Weight Basis
	Family 35	C-O
	CY	Family 35
	C-O	CY-2
	CY-2	CY
	Family 2	CP
	CP	Family 2
	B	Family 13
	CP-1	B
	Family 13	CY-1
	CY-1	CP-1

TABLE V (a). Age group measurements in Family 2 guinea pigs.
(a) Actual weight.
(b) Percentage of live weight.

Age group (days)	No.	Live Weight	Front Quarters	Hind Quarters	Loin	Heart	Lungs	Liver	Kidneys	Spleen	Eyes	Pituitary	Thyroid	Adrenals	Testicles	Length Small Intestine	Length Large Intestine
360 - 449	22	649.8	46.6	58.7	44.5	1.83	3.48	20.66	4.93	.7629	1.1437	.0159	.0833	.6868	3.89	155.2	109.9
450 - 539	2	667.3	49.2	61.9	42.6	2.10	4.37	25.16	5.28	1.0296	1.2795	.0155	.0972	.7488	4.18	151.8	113.0
540 - 629	15	672.4	47.2	60.3	45.1	2.06	4.58	25.82	5.54	.7811	1.2432	.0159	.0934	.8592	3.88	152.7	116.6
630 - 719	9	646.8	45.1	56.7	45.7	2.02	5.57	24.76	4.96	.6698	1.2827	.0156	.0881	.8234	3.78	144.8	108.9
720 - 809	5	649.4	43.7	56.9	41.4	1.89	4.55	23.75	5.76	.7424	1.2854	.0160	.0885	.9811	3.90	140.5	107.1
810 - 899	6	731.3	51.3	63.5	50.1	2.02	4.84	23.69	5.55	.8714	1.3509	.0165	.1037	.9546	--	162.6	114.4
900 +	11	703.8	50.0	58.8	46.6	2.29	4.47	22.88	5.81	.7677	1.3928	.0167	.1128	1.1212	2.57	158.2	115.7
Total Males	70	670.2	47.4	59.2	45.3	2.00	4.47	23.25	5.33	.7710	1.2447	.0160	.0932	.8553	3.66	153.3	112.4
Total Females	11	660.5	44.5	54.7	43.9	2.03	4.58	22.82	5.76	.9707	1.3839	.0160	.1143	.8633	--	166.4	109.7

TABLE V (b).

Age group (days)	No.	Live Weight	Front Quarters	Hind Quarters	Loin	Heart	Lungs	Liver	Kidneys	Spleen	Eyes	Pituitary	Thyroid	Adrenals	Testicles	Length Small Intestine	Length Large Intestine
360-449	22		7.17	9.03	6.85	.282	.591	3.18	.759	.1174	.1760	.0024	.0128	.1057	.598		
450 - 539	2		7.38	9.28	6.38	.314	.655	3.77	.791	.1542	.1917	.0023	.0146	.1122	.626		
540 - 629	15		7.02	8.97	6.71	.306	.681	3.84	.824	.1161	.1849	.0024	.0139	.1278	.538		
630 - 719	9		6.97	8.76	7.06	.312	.861	3.83	.767	.1036	.1983	.0024	.0136	.1273	.584		
720 - 809	5		6.73	8.76	6.38	.291	.701	3.66	.887	.1143	.1980	.0025	.0136	.1511	.601		
810 - 899	6		7.01	8.68	6.85	.276	.662	3.24	.759	.1191	.1847	.0022	.0142	.1305	--		
900 +	11		7.10	8.35	6.62	.325	.635	3.25	.825	.1090	.1978	.0024	.0160	.1592	.365		
Total Males	70		7.07	8.86	6.77	.300	.671	3.48	.799	.1154	.1842	.0024	.0139	.1279	.560		
Total Females	11		6.74	8.27	6.65	.307	.693	3.45	.872	.1469	.2095	.0024	.0173	.1307	--		

TABLE VI. Significant differences of measurements between age groups and sex in Family 2 guinea pigs.
(Asterisk at left signifies actual measurements; at right, percentage measurements).

Groups[x]	Live † Weight	Front Quarter		Hind Quarter		Loin		Heart		Lungs		Liver		Kidneys		Spleen		Eyes		Pituitary		Thyroid		Adrenals		Testicles		Length Small † Intestine	Length Large † Intestine	$N_1 + N_2$
1 - 3								*	*	*	*	*	*	*	*			*						*	*		*		*	35
4								*	*	*	*	*	*			*	*	*						*	*		*	*		29
5			*								*		*	*	*			*						*	*		*	*		25
6	*							*		*				*				*						*	*	---				26
7					*			*	*			*		*				*	*			*	*	*	*	*	*			30
3 - 4														*		*													*	22
5																														18
6													*					*								---				19
7					*								*					*				*	*	*	*	*	*			23
4 - 5														*	*										*					12
6	*	*												*		*								*		---		*		13
7	*	*					*				*			*		*						*		*	*	*	*	*		17
5 - 6		*																								---		*		9
7		*																								*	*	*		13
6 - 7																								*	*	---				14
Males & Females			*		*										*	*	*		*			*	*			---		*		81

x Group 2 (450 - 539 days) was not included because of only 2 observations.

† Only actual measurements are concerned in these data.

TABLE VII. Coefficients of Correlation Between Various Measurements in Different Lines of Guinea Pigs

Factors Correlated	Family 2 Actual N	Family 2 Actual Coeff. Cor.	Family 2 Percentage N	Family 2 Percentage Coeff. Cor.	Family 13 Actual N	Family 13 Actual Coeff. Cor.	Family 13 Percentage N	Family 13 Percentage Coeff. Cor.	B Stock Actual N	B Stock Actual Coeff. Cor.	B Stock Percentage N	B Stock Percentage Coeff. Cor.
Live Weight by Weight of Hind Quarters	80	.797			30	.873			34	.352		
" " " " " Front "	80	.840			30	.886			34	.558		
" " " " " Loin	80	.795			30	.832			34	.663		
" " " " " Heart	80	.384			29	.446			34	.735		
" " " " " Lungs	80	.135			30	.330			33	.143		
" " " " " Liver	79	.375			29	.595			34	.776		
" " " " " Kidneys	80	.292			30	.326			34	.179		
" " " " " Spleen	80	.402			30	.121			34	.097		
" " " " " Eyes	65	.358			29	.579			34	.431		
" " " " " Pituitary	78	.322			30	.259			34	-.070		
" " " " " Thyroid	79	.370			30	.548			34	.454		
" " " " " Adrenal	80	.351			30	.196			34	.152		
" " " " " Testicles	50	.335			26	.651			30	.407		
" " " Length Small Intestine	79	.468			30	.438			34	.467		
" " " " Large "	79	.470			30	.750			34	.532		
Weight Hind Quarter by Weight Front Quarter	80	.799	81	.340	30	.910	30	.721	34	.686	34	.715
" " " " " Loin	80	.726	81	.047	30	.907	30	.623	34	.678	34	.363
" Front " " " "	80	.778	81	.255	30	.856	30	.370	34	.775	34	.631
" Heart by Weight Lungs	80	.247	81	.331	29	.072	29	.080	33	.156	33	.223
" " " " Liver	79	.340	80	.125	28	.504	28	.363	34	.684	34	.291
" " " " Kidneys	80	.556	81	.630	29	.497	29	.619	34	.314	34	.588
" " " " Spleen	80	.330	81	.110	29	.200	29	.490	34	.070	34	.321
" " " " Pituitary	78	.514	79	.509	29	.002	29	.190	34	-.016	34	.218
" " " " Thyroid	79	.244	80	.143	29	.187	29	-.122	34	.203	34	-.142
" " " " Adrenal	80	.430	81	.360	29	-.036	29	.021	34	.193	34	.182
" " " " Testicles	50	.047			25	.121			30	.187		
" " " Length Small Intestine	79	.133			29	.189			34	.259		
" " " " Large "	79	.258			29	.471			34	.300		
" Lungs by Weight Liver	79	.458										
" " " " Kidneys	80	.317										
" " " " Spleen	80	.048										
" " " " Pituitary	78	.345	79	.375	30	.513	30	.486	33	-.032	33	.107
" " " " Thyroid	79	.142	80	.084	30	.413	30	.186	33	.209	33	.083
" " " " Adrenal	80	.305	81	.312	30	.491	30	.483	33	.260	33	.186
" " " " Testicles	50	.112										
" " " Length Small Intestines	79	-.084										
" " " " Large "	79	.104										
" Liver by Weight Kidneys	79	.122										
" " " " Spleen	79	.117										
" " " " Pituitary	77	.190	78	.096	29	.045	29	-.394	34	-.313	34	-.251
" " " " Thyroid	78	.288	79	.164	29	.267	29	-.114	34	.375	34	.110
" " " " Adrenal	79	.322	80	.089	29	.316	29	.377	34	.721	34	.154
" " " " Testicles	50	.119										
" " " Length Small Intestine	79	.040										
" " " " Large "	79	.233										

TABLE VII (Cont'd.). Coefficients of Correlation Between Various Measurements in Different Lines of Guinea Pigs

Factors Correlated	Family 2				Family 13				B Stock			
	Actual		Percentage		Actual		Percentage		Actual		Percentage	
	N	Coeff. Cor.	N	Coeff. Cor.	N	Coeff. Cor.	N	Coeff. Cor.	N	Coeff. Cor.	N	Coeff. Cor.
Weight Kidneys by Weight Spleen	80	.436										
" " " " Pituitary	78	.465	79	.560	30	.325	30	.392	34	-.190	34	.456
" " " " Thyroid	79	.264	80	.150	30	.339	30	.096	34	-.065	34	-.108
" " " " Adrenal	80	.513	81	.340	30	.357	30	.351	34	.537	34	.105
" " " " Testicles	50	.288										
" " " Length Small Intestines	79	.232										
" " " " Large "	79	.343										
" Spleen by Weight Pituitary	78	.172	79	.255	30	-.081	30	.091	34	-.274	34	-.116
" " " " Thyroid	79	.283	80	.196	30	.030	30	-.077	34	-.128	34	-.115
" " " " Adrenal	80	.161	81	.052	30	.146	30	.253	34	.227	34	.188
" " " " Testicles	50	.182										
" " " Length Small Intestines	79	.379										
" " " " Large "	79	.213										
" Pituitary by Weight Thyroid	78	.118	79	.022	30	.485	30	.298	34	-.106	34	-.048
" " " " Adrenal	78	.337	79	.297	30	.635	30	.604	34	-.248	34	-.079
" " " " Testicles	48	.261	52	-.003	26	.561	26	.587	30	.080	31	.321
" " " Length Small Intestines	77	.106										
" " " " Large "	77	.085										
" Thyroid by Weight Eyes	65	.459										
" " " " Adrenal	79	.379	80	-.320	30	.544	30	.472	34	.029	34	-.039
" " " " Testicles	49	-.158	53	-.401	26	.502	26	.148	30	.144	31	-.187
" " " " Small Intestines	78	.442										
" " " " Large "	78	.204										
" Adrenal by Weight Testicles	50	-.307	54	-.492	26	.359	26	.354	30	.353	31	.364
" " " Length Small Intestines	79	.098										
" " " " Large "	79	.237										
" Testicles by Length Small Intestines	50	.042										
" " " " Large "	50	.059										
Length Small by Length Large Intestine	79	.308			30	.654			34	.590		
Age by Live Weight of Males	69	.264										
" " " " " Females	11	.157										
" " " " " Males and Females	80	.176			30	.147			34	.277		
" " Weight of Heart	80	.520	81	.378	29	-.146	29	-.273	34	.188	34	-.194
" " " " Lungs	80	.218	81	.166	30	.122	30	.016	33	.320	33	.178
" " " " Liver	79	-.048	80	-.154	29	.007	29	-.126	34	.286	34	.084
" " " " Kidneys	80	.654	81	.503	30	.072	30	-.031	34	.078	34	-.163
" " " " Spleen	80	.478	81	.237	30	.391	30	-.198	34	-.006	34	-.135
" " " " Eyes	65	.887	66	.672	29	.723	29	.421	34	.469	34	-.017
" " " " Pituitary	78	.398	79	.224	30	.501	30	.409	34	-.050	34	-.180
" " " " Thyroid	79	.440	80	.391	30	.336	30	.362	34	.654	34	.591
" " " " Adrenal (Males)	69	.744	81	.581	30	.606	30	.658	34	.027	34	-.041
" " " " Testicles	50	-.417	54	-.854	26	.045	26	-.124	30	-.120	31	-.429
" " Length Small Intestines	80	.315			30	.437			34	-.082		
" " " Large "	80	.153			30	.198			34	.093		
" " Weight of Hind Quarters	81	-.120	81	-.557	30	.064	30	-.160	34	-.138	34	-.561
" " " " Front "	81	.048	81	-.187	30	.001	30	-.356	34	.089	34	-.205
" " " " Loin	81	-.002	81	-.190	30	.096	30	-.002	34	-.040	34	-.260

TABLE VIII. Percentage of bone in quarters in groups of guinea pigs.

Group	Statistic	Weight of bones of front quarter	Percent of bone to total weight of quarter	Weight of bones in hind quarter	Percent of bone to total weight of quarter	Average C.V.
Family 2	M	1.8684	7.65	2.3496	7.90	
		.1913	.575	.2218	.571	
	C.V.	10.24	7.52	9.44	7.23	8.61
Family 13	M	1.9796	6.66	2.4135	6.54	
		.1876	.639	.2230	.542	
	C.V.	9.48	9.59	9.24	8.29	9.15
Family 35	M	1.9980	7.03	2.3758	6.68	
		.0976	.452	.0869	.499	
	C.V.	4.88	6.43	3.66	7.47	5.61
Control B	M	2.2139	6.78	2.6704	6.71	
		.2071	.733	.2402	.512	
	C.V.	9.35	10.81	8.99	7.63	9.19
CY	M	2.0475	7.71	2.5594	7.57	
		.0879	.645	.2839	.705	
	C.V.	4.29	8.37	11.09	9.31	8.26
CY-1	M	2.0556	7.79	2.4888	7.61	
		.1927	.493	.2168	.539	
	C.V.	9.37	6.33	8.71	7.08	7.87
CY-2	M	2.0255	7.78	2.5018	7.44	
		.2341	.547	.2137	.571	
	C.V.	11.55	7.03	8.54	7.67	8.69
CP	M	2.2095	6.85	2.6658	6.58	
		.1805	.446	.1745	.466	
	C.V.	8.17	6.51	6.55	7.08	7.08
CP-1	M	2.0674	6.89	2.4695	6.76	
		.2779	.375	.3088	.365	
	C.V.	13.44	5.44	12.50	5.40	9.19
C-0	M	2.1582	7.18	2.6047	7.17	
		.2216	.793	.2821	.597	
	C.V.	10.27	11.04	10.83	8.33	10.12
C-1	M	1.9712	8.00	2.4404	8.00	
		.2297	.445	.2840	.335	
	C.V.	11.65	5.56	11.64	4.19	8.26
Average variability	C.V.	9.19	8.55	8.87	7.62	8.56

TABLE XIII. Bone weight and bone length in groups of guinea pigs.

	Bone Weight (grams)					Humerus Length (inches)			Ulna Length (inches)			Femur Length (inches)			Tibia Length (inches)		
Group	Scapula	Humerus	Ulna and Radius	Femur	Tibia and Fibula	M	σ	C.V.	M	σ	C.V.	M	σ	C.V.	M	σ	C.V.
Family 2 (males)	.5232	.8012	.6179	1.3539	1.0829	1.508	.0250	1.66	1.626	.0583	3.59	1.832	.0239	1.30	1.993	.0344	1.73
(females)	.4445	.6809	.5507	1.1587	.9608	1.464	.0250	1.40	1.607	.0491	3.06	1.760	.0206	1.17	1.929	.0310	1.61
Family 13	.5517	.7911	.6368	1.3333	1.0801	1.481	.0310	2.09	1.697	.0557	3.28	1.805	.0400	2.22	1.976	.0477	2.41
Family 35	.5692	.8280	.6008	1.3121	1.0637	1.549	.0179	1.16	1.710	.0332	1.94	1.818	.0317	1.74	1.987	.0371	1.87
B	.6225	.8994	.7023	1.4895	1.1952	1.552	.0303	1.95	1.744	.0533	3.06	1.869	.0440	2.35	2.033	.0454	2.23
C-0	.6024	.8784	.6828	1.4239	1.1808	1.539	.0422	2.74	1.602	.0899	5.61	1.828	.0353	1.93	2.009	.0604	3.01
C-1 (male)	.5290	.7921	.6500	1.3318	1.1085	1.484	.0280	1.89	1.679	.0300	1.79	1.780	.0160	.90	1.946	.0395	2.03
(female)	.4155	.7042	.5194	1.2096	.8969												
CY	.5545	.8407	.6521	1.4095	1.1498	1.517	.0049	.32	1.697	.0157	.93	1.849	.0128	.69	2.004	.0127	.63
CY-1 (male)	.5731	.8286	.6668	1.3562	1.1325	1.506	.0371	2.46	1.691	.0399	2.36	1.825	.0428	2.35	1.979	.0510	2.58
(female)	.4432	.7224	.6253	1.1190	.9133	1.493	.0477		1.632	.0201		1.799	.0540		1.960	.0372	
CY-2 (male)	.5535	.8133	.6555	1.3432	1.1420	1.496	.0335	2.24	1.695	.0394	2.32	1.807	.0436	2.41	1.978	.0411	2.08
(female)	.4443	.7038	.5597	1.1506	.9590	1.432	.0460		1.641	.0445		1.769	.0430		1.931	.0470	
CP	.6226	.8868	.7000	1.4633	1.2023	1.541	.0452	2.93	1.745	.0439	2.52	1.847	.0496	2.69	2.023	.0567	2.80
CP-1 (male)	.5779	.8496	.6398	1.3844	1.1183	1.506	.0384	2.55	1.712	.0306	1.79	1.805	.0237	1.31	1.977	.0455	2.30
(female)	.5010	.7678	.5783	1.2641	1.0350	1.541	.0020		1.701	.0145		1.821	.0110		1.979	.0080	

TABLE IX. Significant differences of percent of bone to total quarter.
(Asterisk signifies significant difference)

Group	Front Quarter		Hind Quarter		$N_1 + N_2$
	Weight	Percent	Weight	Percent	
Family 2 and 13	*	*		*	68
35	*	*		*	53
B	*	*	*	*	71
CY	*		*		46
CY-1	*				51
CY-2	*				45
CP	*	*	*	*	48
C-O	*	*	*	*	54
Family 13 and 35					43
B	*		*		61
CY		*		*	36
CY-1		*		*	41
CY-2		*		*	35
CP	*		*		38
C-O	*	*	*	*	44
Family 35 and B	*		*		46
CY		*	*	*	21
CY-1		*		*	26
CY-2		*		*	20
CP	*		*		23
C-O	*		*		29
B and CY		*		*	39
CY-1	*	*	*	*	44
CY-2	*	*		*	38
CP					41
C-O				*	47
CY and CY-1					19
CY-2					13
CP		*		*	16
C-O					22
CY-1 and CY-2					18
CP		*		*	21
C-O		*			27
CY-2 and CP		*		*	15
C-O					21
CP and C-O				*	24

TABLE X. Ratio of spleen length to width in groups of guinea pigs.

Group	Length mm.	Width mm.	Ratio L : W	No.
Family 2	33.5	13.6	2.46:1	32
13	28.1	13.8	2.04	27
35	23.0	13.7	1.67	14
B	29.5	14.1	2.09	27
CY	31.3	14.4	2.17	5
CY-1	30.1	14.0	2.15	15
CY-2	28.7	13.6	2.12	8
CP	26.7	14.3	1.86	6
CP-1	28.1	13.9	2.02	5
C-O	29.9	14.2	2.10	15
C-1	30.5	13.8	2.21	2

TABLE XI. Ratio of length of small to large intestines.

Group	Length of Small Intestine (cm.)	Length of Large Intestine (cm.)	Ratio S : L	No.
Family 2 (males)	153.3	112.4	1.36:1	70
(females)	166.4	109.7	1.52	10
Family 13	158.6	106.3	1.49	30
35	157.5	112.7	1.40	14
B	170.6	116.8	1.46	34
CY	160.0	114.2	1.40	9
CY-1 (males)	153.1	109.3	1.40	19
(females)	166.6	108.2	1.54	4
CY-2 (males)	153.9	108.2	1.42	11
(females)	151.5	104.2	1.45	2
CP	166.0	112.9	1.47	10
CP-1 (males)	157.7	111.3	1.42	6
(females)	169.8	108.0	1.57	2
C-O	162.9	115.9	1.41	15
C-1 (males)	162.2	107.1	1.51	2
(females)	161.1	110.8	1.45	1

TABLE XII (a). Amount of calcium, phosphorus and catalase in blood of guinea pigs.

Group	Calcium mg. per 100 cc.	Phosphorus mg. per 100 cc.	Ratio Ca:P	Catalase cc.O_2 per .5 cc blood
Family 2	11.4	4.19	2.71:1	84.23
13	10.6	3.65	2.90	78.31
35	9.2	3.83	2.40	80.65
B	11.1	3.68	3.02	74.20
C-0	7.9	4.05	1.95	82.61
C-1	8.9	3.71	2.40	82.92
CY	10.8	4.91	2.20	74.24
CY-1	9.6	3.78	2.54	79.09
CY-2	8.0	3.87	2.07	82.86
CP	11.6	4.93	2.35	74.19
CP-1	8.5	3.22	2.64	57.90
Total Average	10.5	3.97	2.64	78.88

TABLE XII (b). Calcium, Phosphorus, and Catalase of the blood in relation to month of the year in which guinea pigs were slaughtered.

Factor Measured	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Calcium	8.7	7.3	10.2	12.0	13.3	10.9	12.2	10.5	9.7	11.0	10.5	-
Phosphorus	2.28	4.16	4.60	4.74	6.72	4.08	3.47	4.21	5.43	1.94	4.20	-
Ratio Ca:P	3.81	1.75	2.22	2.53	1.98	2.67	3.51	2.49	1.79	5.67	2.50	-
Catalase (cc.O_2)	82.36	53.01	75.25	86.50	-	76.20	74.19	79.53	79.85	83.15	84.79	-

TABLE XIV. Significant differences of bone length between groups of guinea pigs. Asterisk indicates significant difference.

Groups	Humerus	Ulna	Femur	Tibia	$N_1 + N_2$
Family 2, males and females	*		*	*	40
Family 2 and 13	*	*	*		58
35	*	*			43
B	*	*		*	59
C-O	*				44
CY					36
CY-1					42
CY-2			*		35
CP	*	*			35
Family 13 and 35	*				43
B		*		*	59
C-O	*	*			44
CY	*		*		36
CY-1					42
CY-2					35
CP	*		*	*	35
Family 35 and B		*	*	*	44
C-O		*			29
CY	*		*		21
CY-1	*				27
CY-2	*				20
CP					20
B and C-O		*	*		45
CY	*	*			37
CY-1	*	*	*	*	43
CY-2	*	*	*	*	36
CP					36
C-O and CY		*			22
CY-1		*			28
CY-2	*	*			21
CP		*			21
CY and CY-1					20
CY-2					13
CP		*			13
CY-1 and CY-2					19
CP		*			19
CY-2 and CP					12

TABLE XV. Correlations of bone length measurements.

Bones correlated	Family 2	Family 13	B
Humerus with Ulna	.676	.733	.761
Femur	.694	.763	.793
Tibia	.729	.893	.875
Ulna with Femur	.454	.794	.816
Tibia	.845	.769	.817
Femur with Tibia	.705	.855	.901

TABLE XVI. Summary of fat color in different lines of guinea pigs. Number of animals showing fat of the various colors designated.

Group	Yellow	Light Yellow	Cream	Light Cream	Very Light Cream	White	Total
Family 2	35	17		1			53
13		5	2	16	6		29
35		2	1	8	3		14
B		1	5	8	12	8	34
CY	1	2		4			7
CY-1	6	4	2	2	3		17
CY-2	1	4	1	1	1		8
CP			3	2	4		9
CP-1	1	1		1	2		5
C-0	2	4	2	2	5		15
C-1		1	1		1		3
Total	46	41	17	45	37	8	194