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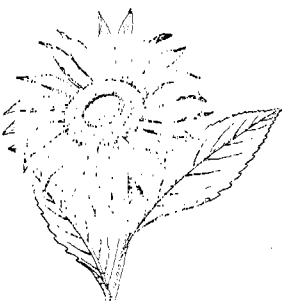
KANSAS STATE AGRICULTURAL COLLEGE
MANHATTAN, KANSAS

CROSSBRED POULTRY



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SUMMARY

1. Crosses between the Single Comb White Leghorn and Jersey Black Giant showed the resulting hybrids to be superior to the two pure breeds in all measurements of vigor.

2. The results from the Single Comb White Leghorn-Single Comb Rhode Island Red cross showed the hybrids to be generally superior to the pure breeds, but in a few comparisons the hybrids only equaled the better of the two breeds involved.

3. The crosses of Single Comb White Leghorns by Barred Plymouth Rocks and of Single Comb Rhode Island Reds by Barred Plymouth Rocks produced hybrids that in each case were superior to the pure breeds involved, for chick mortality and rate of growth, these being the only criteria of vigor considered.

4. Crosses between independently bred strains of Single Comb White Leghorns produced offspring that were in some respects superior to the pure strain progeny, but the degree of stimulation did not appear to be so great as in the crosses of different breeds.

5. Sex of chicks may be distinguished at hatching by means of sex-linked down colors in crossbred chicks.

6. The new method utilizing the growth of wing feathers at hatching is slightly less accurate for identifying the sexes, but has certain advantages over the down-color method.

7. The advantages of the wing feather growth method are that it makes available the White Leghorn breed, which is widely popular and well bred for production; it produces a white hybrid; and greatly extends the list of breeds available for crossing to distinguish sex at hatching.

8. The superior vigor of some hybrids probably makes them more economical than most pure breeds for the poultryman whose major income is from market poultry and eggs.

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CROSSBRED POULTRY[1]

D. C. WARREN

HYBRID VIGOR

NATURE OF HYBRID VIGOR

The exceptional sturdiness of crossbreds resulting from the mating of breeds and varieties of domestic animals has long been a matter of common knowledge among practical breeders. This sturdiness has been referred to as hybrid vigor and has not been limited to the animal kingdom, since commercial use is now being made of crossbred corn. The production of hybrid corn requires the service of a skilled breeder, while animal hybrids may be produced with no additional cost except that involved in providing one parent of a different breed.

Use has been made of crossbreds in sheep, swine, and cattle breeding. Such hybrids have been found to be exceptionally thrifty and rapid-growing, making very desirable meat-type animals. In spite of the commercial use of hybrids there has been very little careful experimentation to determine accurately the amount of stimulation induced by crossbreeding. The use of crossbreds is much more general in England than in America.

Probably the most familiar hybrid is the mule resulting from the crossing of the horse and the ass. As is the case where the two forms are very widely different, the mule is a sterile hybrid, usually being incapable of producing offspring. The mule exhibits the characteristic vigor of hybrids and combines many of the desirable qualities of the two types crossed. Although the evidence from crossbreeding is not entirely conclusive, it supports the view that the more divergent the forms being crossed the greater the stimulation.

Another characteristic of hybrid vigor which should be emphasized here is its limitation to the first generation. This makes it impossible to breed from hybrids and is the characteristic which makes the distinction between hybrids and mongrels. The hybrid is characterized by exceptional sturdiness, rapid growth, and uniformity of all its characteristics, while the offspring of hybrids show wide variability in size, conformation, and color and frequently do not have vigor equal to that of the original parental types. The exceptional qualities of hybrids frequently lead the producer to make the error of attempting to use them as breeders.

1. Contribution No. 58 from the Department of Poultry Husbandry.

CROSSBREEDING POULTRY

To the average poultry breeder it may appear inconsistent to suggest the practice of crossbreeding after years of proclaiming the gospel of pure breeding. The use of the pure or standard-bred fowl was urged because it had been improved by skilled breeders and made a more productive and uniform market animal, and when comparing the pure bred and the mongrel all these advantages exist. However, the hybrid fowl, except for color in a few crosses, is more uniform than most standard breeds and in vigor and productiveness it is superior to the breeds used in its origin. The work in plant breeding would indicate that the best results may be expected from crossing of breeds and varieties that have survived a period of breeding toward a definite standard. The utilization of the hybrid is not a reversion to the old system of promiscuous breeding, but the adoption of a system which is of value only when well-bred standard fowl are available. The poultryman, noted for his exact standards, has built up breeds and varieties that provide favorable material for crossbreeding. If the use of crossbreds becomes widespread it will not mean the reversion to mongrelization of the fowl, but will place a premium upon well-bred pure breeds. It will have a tendency to place poultry breeding in the hands of the specialist, since in his keeping is the material which must be used to replenish the stock of the user of crossbreds.

Since hybrids cannot be used as breeders they make no appeal to the poultryman who depends upon the sale of breeding stock and hatching eggs for a portion of his income. There are, however, many poultrymen who confine their operations to market eggs and poultry. This group should find the hybrid most profitable. Many of this group depend upon the hatcheryman for their supply of chicks. To this type of an organization the hybrid fowl lends itself most favorably. It is a relatively simple matter for the hatcheryman to arrange his flocks for the production of crossbreds, and the improved hatchability would probably more than pay the additional cost of the operation, The possibility of identifying the sexes at hatching, which is discussed later in this publication, is an additional factor in favor of the hybrid. Hatcherymen are already finding ready sale for crossbred chicks.

USE OF CROSSBRED POULTRY

Hybrid poultry is not entirely new. For years producers in some of the eastern states have resorted to crossbreeding for the production of rapid-growing table fowls. Yet very little use has been

made of hybrids for the production of eggs. In England, however, hybrid poultry has during recent years become very popular. One of the outstanding differences between the poultry industry in England and America, according to R. T. Parkhurst, director of the Institute of Poultry Husbandry, New Port, Salop, England, is the utilization of the hybrid fowl in that country. In the 1928-'29 National Egg Laying Test of the British Isles there were included first-generation hybrids that have given very good accounts of themselves. The reports of that year's test show the hybrid group to have a higher average production than any breed entered in the contest. The average of the 156 hybrids entered in the test was 207.5 eggs, while their nearest competitor among the pure breds was White Leghorns, averaging 191.8 eggs. The Rhode Island Reds averaged 186.8 eggs and the White Wyandottes 185.9 eggs, these being two of the best-producing heavier breeds in the test. The hybrids included a number of crosses, and had the average been for only the more productive ones, a much better record would have been made. The fact that hybrids are outyielding the best production strains in England seems to answer the criticism that hybrid vigor is only a restoration of vigor lost through inbreeding, and that nothing new has been produced.

RESULTS OF EXPERIMENTS

Single Comb White Leghorn-Jersey Black Giant Cross

The results of the earliest experiment on the subject of hybrid vigor conducted at the Kansas Agricultural Experiment Station have already been published.[2] In this experiment hybrids were produced by crossing Jersey Black Giants and Single Comb White Leghorns. The first-generation crossbreds were compared with the pure breeds used in their production on the basis of hatchability of eggs, chick mortality, rate of growth, and egg production. In this early study the results from reciprocal crosses were not separated, so the hybrids include offspring from both the mating of Jersey Black Giant male by White Leghorn female and White Leghorn male by Jersey Black Giant female. Figure 1 shows three of the comparisons. From the results it is seen that the crossbreds not only had less mortality and higher egg production, but the eggs producing the hybrids gave a higher per cent of hatch than did eggs producing the two pure breeds involved. Figure 2 presents growth curves comparing the hybrids with the Jersey Black Giants and White Leghorns. From the age of one to twelve weeks the hybrids outgrew the pure breds.

2. Warren, D. C. Hybrid vigor in poultry. Poultry Sci. 7:1-8. 1927.

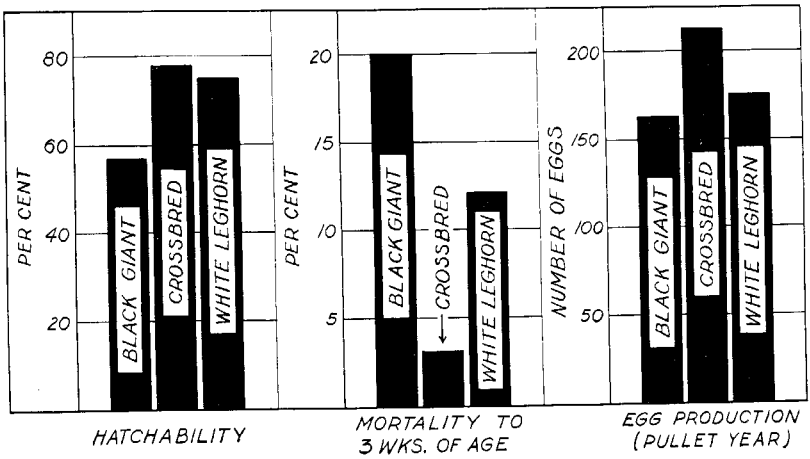

FIG. 1.—Comparing for hatchability, chick mortality, and egg production of White Leghorn-Jersey Black Giant hybrids with the breeds used in their origin.

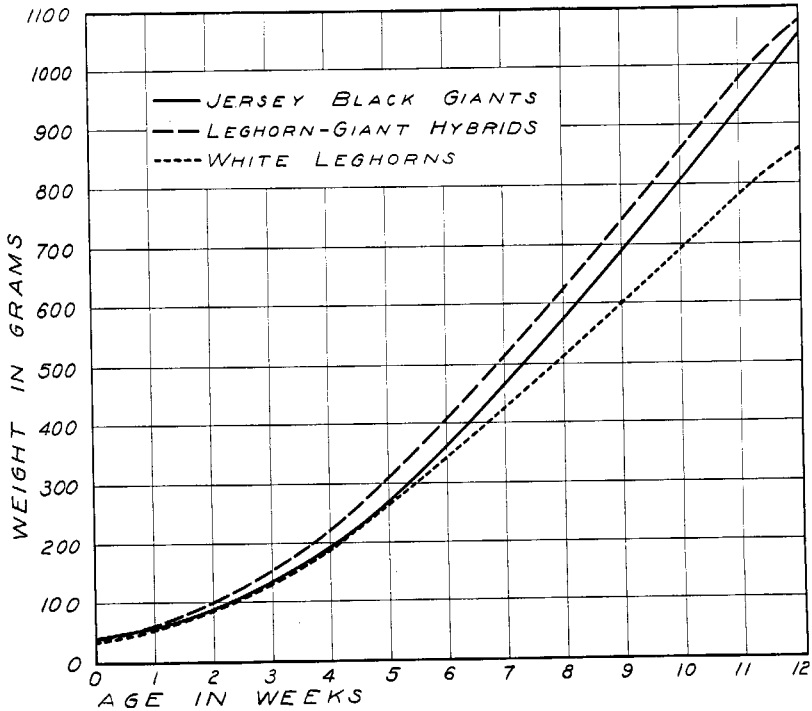

FIG. 2.—Comparison of the weekly growth of White Leghorn-Jersey Black Giant hybrids with the two breeds from which they were produced.

At the six-month age the Jersey Black Giants weighed 2,315 grams (5.1 pounds) ; the White Leghorns, 1,537 grams (3.4 pounds) ; and the hybrids, 2,121 grams (4.7 pounds), Thus, at maturity the crossbreds were intermediate in size but approaching more nearly the larger breed. The weights given are the averages of the male and the female averages.

From all criteria of vigor considered the crossbreds proved to be superior to the two breeds used in their production. (Fig. 3.) Since the results given here were incidental to other information being sought, the following more carefully planned experiment was arranged utilizing two popular breeds :

Single Comb White Leghorn-Rhode Island Red Cross

In this experiment precautions were taken to make the comparisons as critical as possible. All chicks were confined to sanitary hardware cloth runways until eight weeks of age, when they were allowed the freedom of an alfalfa range. As was true in the preceding experiment all hybrid and pure-bred chicks being compared were hatched in the same incubators and all chicks from a single hatch were kept in one brooder house. This made environmental conditions as nearly identical as possible. Too often the inherent qualities of the fowls used in producing experimental stock are ignored. In this experiment the matings were so arranged that all hybrids were half brothers and sisters to the pure breds with which they were being compared. This arrangement reduced as far as possible the influence of the individual genetic variability of the birds used as parents.

The relationship of the hybrids and pure breds was accomplished by a system of rotation of the males used in the experiment. For the production of the chicks to be compared eight breeding pens arranged in a row were used. In alternating pens were placed Single Comb White Leghorn pullets, and Single Comb Rhode Island Red pullets were placed in the intervening ones. For a three-week period previous to the starting of the experiment each pen was headed by a male of the same breed as were the females. The first eggs were saved on Tuesday, January 24, and on the following Saturday night each male was shifted to the adjoining pen. Eggs were placed in the incubator each Tuesday for a period of eight weeks. Males were shifted to the next pen of the series on each Saturday night so that each pen was headed during one week by a male of its own breed and the following week by one of the other

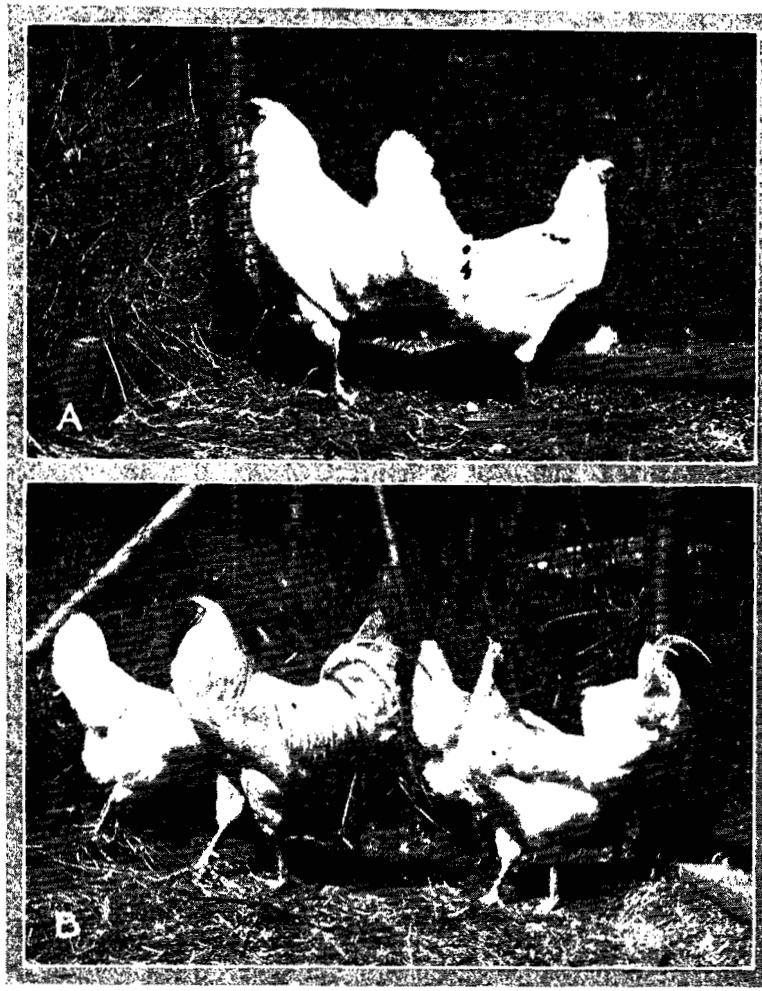

FIG. 3.—(A) First-generation hybrids from the cross of Jersey Black Giant male by White Leghorn female. (B) First-generation hybrids from the cross of White Leghorn male by Jersey Black Giant female.

breed used. This resulted in each pen producing on alternate weeks predominately pure and crossbred chicks. Since it has been found that the sperm of a new male seldom function under twenty-four hours, the offspring of the newly introduced males could not be obtained earlier than from Monday's eggs and more often later. Previous work by the writer[3] had shown that in the case of the

3. Warren D. C., and Kilpatrick, Lester. Fertilization in the domestic fowl. Poultry Sci. 8:237-256. 1929

replacement of one male by another, if the replacing male fertilized any eggs, there was practically no overlapping of offspring from his predecessor. The substituted male's offspring usually began to appear about the third day. These facts were taken into consideration in planning this experiment and it was with unexpected accuracy that the weekly setting dates approached the break between hybrids and pure breds.

There was no difficulty in distinguishing the pure Rhode Island Reds from hybrids produced by the same females, since the Leghorn white is practically dominant to all other colors. Since this is true the separation of the White Leghorn chicks from hybrids by the White Leghorn female was more difficult. However, the crossbred offspring from the Leghorn mothers were usually marked by an occasional black fleck in the down or by a tint of red. Most of the hybrids from Leghorn mothers were also late-feathering and thus could be distinguished from the early-feathering pure breds. A combination of these three distinguishing characteristics eliminated practically all error in classification.

By the system of rotation described, there were produced from the Rhode Island females, pure-bred Rhode Island Red chicks and hybrids from White Leghorn males. Since the same Rhode Island Red males that sired the Rhode Island Red chicks also sired the hybrids from the White Leghorn females, the Rhode Island Red chicks were half brothers and sisters to each lot of crossbreds. The same condition held true for the White Leghorn chicks.

Since the same females produced both pure-bred and hybrid chicks during the hatching season it was not possible to obtain here a comparison of hatchability.

CHICK MORTALITY

There were eight weekly hatches of chicks and, after the first, each lot contained both hybrid and pure-bred chicks. The entire lot of each hatch were kept in one brooder house, thus being subjected to the same environmental conditions. Brooding conditions were apparently very good, since mortality was low in all lots. The per cent of mortality calculated was for the first three weeks, since the deaths following this period are not usually chargeable to any inherent weakness of the stock. There were hatched 256 Rhode Island Reds, 182 White Leghorns, 176 hybrids from the cross Rhode Island Red male by White Leghorn female, and 162 from the cross White Leghorn male by Rhode Island Red female.

TABLE I.—CHICK MORTALITY TO THREE WEEKS OF AGE IN THE RHODE ISLAND RED-WHITE LEGHORN CROSS.

	Total chicks.	Total mortality.	Per cent mortality.
White Leghorns	182	11	6.04
Rhode Island Reds	256	18	7.03
Leghorn ♂ × Red ♀ (*a*)	162	5	3.09
Red ♂ × Leghorn ♀	176	1	0.06

Note.—Statistical treatment has been made of all data presented, and opinions expressed as to the significance of the results are based upon this treatment. Since this publication will probably be most extensively used by poultrymen and hatcherymen, statistical treatment has been eliminated from the tables.

(*a*) Because of space limitations the symbols for male (♂) and female (♀) have been used in this and the following tables.

In Table I are shown the results on chick mortality. Although the per cent of mortality was relatively low for both lots of pure breds, the hybrids were considerably below either of them. The Rhode Island Reds and White Leghorns had a mortality per cent of 7 and 6, respectively. The mating of Rhode Island Red male (♂) by White Leghorn females (♀) gave 0.06 of 1 per cent mortality and the reciprocal mating a mortality of 3.1 per cent. These values are all so low that the difference cannot be said to be significant, but the available evidence is in favor of the hybrids.

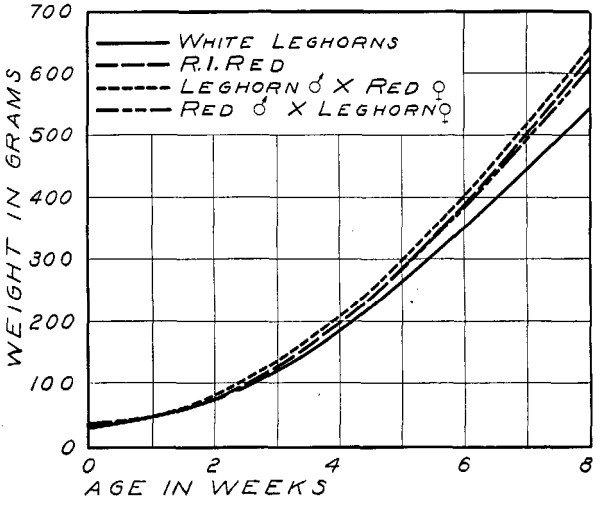

FIG. 4.—Comparison of growth of White Leghorn-Rhode Island Red hybrids with the breeds used in their origin.

RATE OF GROWTH

Individual weights were taken at one day and at two, four, six, eight, twelve, and sixteen weeks for the females and for the males at the same intervals except that they were marketed at eight weeks of age. In all growth studies, day-old weights were taken on the twenty-second day of incubation, and the first weekly weight was taken on the eighth day following. Succeeding weights were taken at seven-day or multiple of seven-day intervals. All weights were taken in the early morning, feed and water having been withheld since the night before. The numbers in each group are given in the discussion of chick mortality. Figure 4 presents the growth curves for the four lots of chicks and the points on the curves are the averages of the male and female averages at the various ages. In Table II the average male and female weights are presented separately to eight weeks of age, when the males were disposed of, but the female weights were continued to sixteen weeks. It is seen that in the case of both sexes the most rapidly growing group to eight weeks of age was that obtained from the mating of White Leghorn male by Rhode Island Red female. At all ages up to eight weeks the chicks of this group were larger than the Rhode Island Reds, the more rapidly growing of the two pure breeds. At twelve weeks of age the Rhode Island Reds surpassed the hybrids, and this change in position was due to the fact that at sexual maturity the Rhode Island Reds were larger than the hybrids. After eight weeks of age the difference in size at maturity begins to have its effect on

TABLE II.—GROWTH OF WHITE LEGHORN AND RHODE ISLAND RED CHICKS, AND THE HYBRIDS RESULTING FROM CROSSING THE TWO BREEDS.

(Weight in grams.)

	White Leghorns.		Rhode Island Reds.		Leghorn ♂ × Red ♀.		Red ♂ × Leghorn ♀.	
	Females.	Males.	Females.	Males.	Females.	Males.	Females.	Males.
No. of chicks.	92	90	120	136	87	75	81	95
Age.								
1 day	32.2	31.9	34.5	34.5	34.5	34.2	33.9	33.8
2 weeks	73.1	75.4	74.7	79.2	81.5	84.8	73.7	80.9
4 weeks	179.0	193.3	184.0	204.4	201.6	220.5	184.4	210.7
6 weeks	330.3	371.2	364.0	413.1	378.2	430.7	355.7	417.3
8 weeks	501.5	581.7	577.3	669.6	592.0	685.3	548.5	664.7
12 weeks	849.4	.....	1,007.9	.....	1,006.3	.....	944.2	.....
16 weeks	1,099.2	.....	1,378.2	.....	1,295.8	.....	1,190.9	.....

rate of growth. The cross of the Rhode Island Red male by White Leghorn female grew somewhat slower than did its reciprocal or opposite cross. To four weeks of age the females of this cross had a growth curve which practically coincided with that of the Rhode Island Reds, and the males were slightly larger than the Rhode Island Red males at all ages up to eight weeks. The White Leghorns grew materially slower than any other group of either sex.

EGG PRODUCTION

In order to compare the two hybrid groups and the two pure breeds involved, 55 females from each of the four groups were placed in a 20- by 40-foot laying house. In choosing the females to be trapnested it was attempted to avoid favoring any particular group. In each lot the birds chosen were selected so as to be equally distributed throughout the eight hatches.

In the comparison each female was allowed 364 days following the first egg, thus allotting each a full 365-day period, regardless of the date of starting. Birds dying before the end of the year were eliminated from consideration. Birds with records of 25 eggs or less were also not considered, since such records under good management are usually due to some pathological condition. In Table III is given the average first-year production for those birds completing the year. In these averages were included 35 Rhode Island Reds, 38 White Leghorns, 47 Rhode Island Red male by White Leghorn female hybrids, and 39 from the reciprocal cross. The hybrids from the cross, White Leghorn male by Rhode Island Red female, were the best producers, having an average (214 eggs) of 3 eggs more than the best-producing pure breed, the White Leghorns. The

TABLE III.—SUMMARY OF THE RESULTS OF THE WHITE LEGHORN-RHODE ISLAND RED CROSS.

	White Leghorns.	Rhode Island Reds.	Leghorn ♂ × Red ♀.	Red ♂ × Leghorn ♀.
Per cent chick mortality to 3 weeks of age	6.0	7.0	3.1	0.06
Average weight in grams at 8 weeks of age (average of male and female average)	541.6	623.5	638.7	606.60
Pullet year egg production	211.6	168.9	214.6	198.70
Per cent of females showing broodiness	5.3	46.0	40.0	83.30
Age at first egg in days	172.4	247.6	175.9	206.40
Egg weight in grams	51.2	54.3	54.6	54.40
Adult female weight in grams	1,738.9	2,567.5	2,153.7	2,070.00

hybrids from the reciprocal cross had an average production of 13 fewer eggs than the White Leghorns. The Rhode Island Reds were the lowest producers, having an average of 168.9 eggs. The highest-producing individual laid 301 eggs and was from the cross of Rhode Island Red male by White Leghorn female. Previously a 282-egg record was made by a hybrid from the cross of Barred Plymouth Rock male by Buff Leghorn female, and a 281-egg record from the cross of White Leghorn male by the Jersey Black Giant female.

AGE AT SEXUAL MATURITY

One of the factors contributing to the differences in egg production was age at sexual maturity. The two pure breeds differed widely with respect to this characteristic. The age at first egg was used as a measure of age at sexual maturity. For the White Leghorns the average age at first egg was 172.4 days and for the Rhode Island Reds, 247.6 days. In figure 5, frequency curves show the distribution of the two pure breeds and the hybrids from them, with respect to age at first egg. The distribution of hybrids from reciprocal

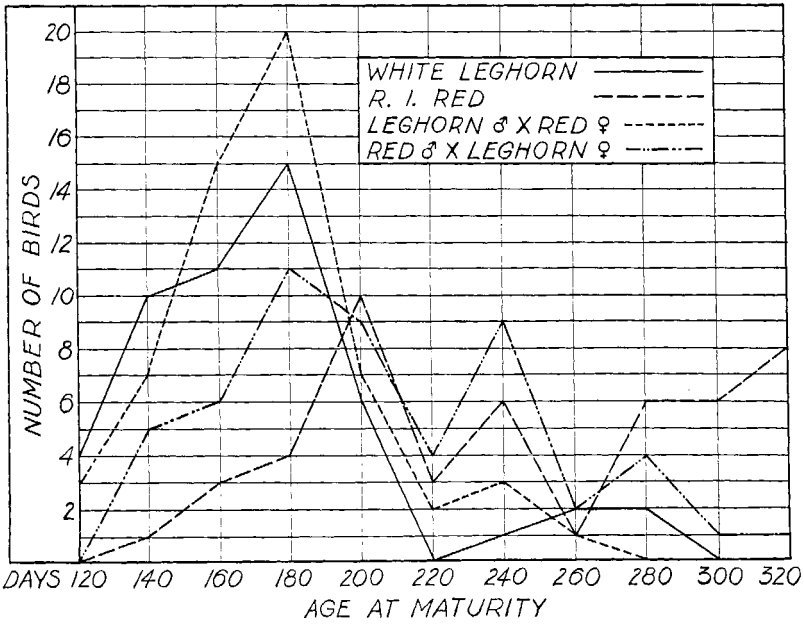

FIG. 5.—Comparison of the age at sexual maturity of White Leghorns Rhode Island Reds, and hybrids resulting from crossing the two breeds.

crosses differed rather widely. The female offspring from the cross of the White Leghorn male by the Rhode Island Red female matured at a much earlier average age than did those from the reciprocal cross having an average maturity age (175.9 days) and distribution similar to that of the White Leghorns. The cross of Rhode Island Red male by White Leghorn females had an average age (206.4 days) at maturity and distribution more or less intermediate between the two breeds crossed. This difference between females from reciprocal crosses suggests that one of the major genetic factors determining the difference in age at sexual maturity between White Leghorns and Rhode Island Reds is sex-linked. Characters due to such factors exhibit the crisscross type of inheritance, the daughters resembling the father and the sons the mother. We have here no record of the maturity of the male offspring, but since the hybrid females having the White Leghorn male as a sire matured much earlier than those that are the daughters of the Rhode Island Red male, we find evidence of crisscross inheritance of age at sexual maturity. Hays has already shown that differences in age at sexual maturity in Rhode Island Reds show this type of inheritance.[4] If this law holds generally for explaining the difference in age at sexual maturity for early and late-maturing breeds, it will be an advantage in crossing to use the male from the earlier maturing breed.

BROODINESS

Since the Rhode Island Red breed shows a high per cent of broodiness and the White Leghorn is relatively free from this trait, the expression of broodiness in their hybrids is of interest. In Table IV the results on broodiness have been summarized. Those females living throughout the summer season of the first laying year (to September 1) were included in the tabulation, excepting those that

TABLE IV.—BROODINESS IN THE WHITE LEGHORN-RHODE ISLAND RED CROSS.

	Leghorns.	Rhode Island Reds.	Leghorn ♂ × Red ♀.	Red ♂ × Leghorn ♀.
Number considered	38	37	40	48
Number broody	2	17	16	40
Per cent broody	5.3	46	40	83.3
Average times broody per bird	1	2.1	2.1	2.5
Average days lost per bird in broodiness	15.5	35.2	28.2	34.9

4. Hays, F. A. Inbreeding the Rhode Island Red fowl with special reference to winter egg production. Amer. Nat. 58:43-59. 1924.

failed to lay during the normal broody period. Out of the 38 White Leghorns 2 birds showed a slight tendency to be broody. The 37 Rhode Island Reds included 17 broody ones, making 46 per cent showing the trait. The 83 per cent of broodiness in the cross of Rhode Island Red male by White Leghorn fernale was unexpectedly high, since it is difficult to account for its being higher than in the pure Rhode Island Reds. In spite of this fact the hybrids from this cross outyielded the Rhode Island Reds, but this handicap, together with later maturity, probably was responsible for their average production being lower than the reciprocal cross. The cross of the White Leghorn male by Rhode Island Red females produced females 40 per cent of which showed broodiness, being very similar to the pure Rhode Island Reds. The difference in results from the two crosses would indicate sex-linked inheritance, but the studies on inheritance of broodiness have not indicated this to be the case.[5] The variation in the genetic constitution of the parental stock may be the responsible factor. Compared on the basis of the average number of days lost in broodiness, the cross of the Rhode Island Red male by White Leghorn female and the pure Rhode Island Reds were very similar, about 35 days. The cross utilizing the White Leghorn male produced females with an average loss of 28 days.

EGG SIZE

Records were taken on egg size of the pullets from the reciprocal crosses and the two groups of pure breds. Egg weights in grams were taken for two fifteen-day periods beginning December 15 and May 15. The average egg weight for each female was calculated from 10 eggs, taking 5 consecutive eggs in each period. Records were obtained on 43 White Leghorns, 43 Rhode Island Reds, 50 from the cross of White Leghorn male by Rhode Island Red female, and 52 from the cross of Rhode Island Red male by White Leghorn female. The average egg weight (Table III) for White Leghorns was 51.2 grams; Rhode Island Reds, 54.3 grams; White Leghorn male by Rhode Island Red female, 54.6 grams; and Rhode Island Red male by White Leghorn female, 54.4.

The average egg from the Rhode Island Red females was larger than that from the White Leghorns. The hybrids from each cross produced slightly larger eggs than did the Rhode Island Reds. Previous work[6] had shown that there was a positive correlation

5. Goodale, H. D., Sanborn, Ruby, and White, Donald. Broodiness in domestic fowl. Mass. Agr. Expt. Sta. Bul. 199:91-116. 1920.

6. Lippincott, William A., Parker, Sylvia L., and Schaumburg, Luella M. The correlation between age at laying of first egg and the weight of eggs during the first laying year in White Leghorns. Poultry Sci. 4:127-140. 1925.

between egg size and age at sexual maturity, that is, the earlier the maturity the smaller the egg, and *vice versa.* It is of interest to note that although the hybrids had an average maturity age of considerably less than the Rhode Island Reds, their egg size was very similar. The average egg size was even a little larger for the hybrids, but the difference was too small to be considered significant. Although the hybrids from the two crosses had a very different maturity age, their egg size was very similar. It therefore appears that there are here operating, factors influencing egg size which do not hold for data taken on egg-size variations within the breed as were Lippincott's figures.

EGG COLOR

For the comparison of the egg color of the hybrid females from reciprocal crosses, a nine-grade standard was made. The grades, 1 to 9, were evenly distributed from a chalk white to the most extreme dark brown. The color grade of a female's eggs was determined by selecting an average egg from among five eggs produced during December, or during February for those not laying during the former month. The grade most nearly matching the egg color was recorded as a female's classification. The Rhode Island Red mothers had a color range from grades 6 to 9 and the White Leghorn female eggs were all of grade 1. Table V presents the comparison, and it is seen that the distribution of color is similar in the two crosses, with the daughters of the Leghorn male producing slightly lighter-colored eggs. The range was from grade 1 to the darkest grades of the mothers, and the mode was between grades 3 and 7. Thus, a majority of the hybrids laid eggs that were intermediate between the egg colors of the parent breeds.

TABLE V.—EGG COLOR IN THE WHITE LEGHORN-RHODE ISLAND RED HYBRIDS.

	Grades of egg color.							
	1	2	3	4	5	6	7	8
White Leghorn ♂ × Rhode Island Red ♀	9	4	14	9	7	5	1	1
Rhode Island Red ♂ × White Leghorn ♀	3	2	15	9	9	9	1	1

ADULT SIZE

The weights given were taken on March 1, since at this time adult weight should have been reached. Thirty-eight White Leghorn females had an average weight of 1,738.9 grams or 3.8 pounds. (See Table III.) The Rhode Island Reds averaged 2,567.5 grams or 5.7

pounds. The hybrids were intermediate in weight, those produced from the Rhode Island Red males weighing 2,070 grams (4.6 pounds) and those from the White Leghorn males averaging 2,153.7 (4.8 pounds). There is, therefore, no evidence that the direction of the cross influences the adult size of the hybrids.

SUMMARY OF RESULTS

A summary of the studies made on the White Leghorn-Rhode Island Red cross (Table III) shows the hybrids to be superior in most comparisons. The chick mortality of the hybrids was lower than in either pure breed. To eight weeks of age the cross of White Leghorn male by Rhode Island Red female showed the most rapid growth, while the cross using the Rhode Island Red male grew at a rate slower than the Rhode Island Reds, but more rapidly than the White Leghorns. The cross of White Leghorn male by Rhode Island Red female had an average pullet-year production of three eggs more than the White Leghorns, which were the better producers of the two pure breeds. The reciprocal cross did not lay so well as the White Leghorns, but considerably better than the Rhode Island Reds. The only comparison in which the hybrids appeared conspicuously inferior to the pure breds was in their tendency toward broodiness. The cross of Rhode Island Red male by White Leghorn female showed a very high per cent of broodiness. Eighty-three per cent of the females in this mating exhibited some tendency toward broodiness, while the pure Rhode Island Reds were only 46 per cent broody. The cross utilizing the White Leghorn male had considerably less broodiness than its reciprocal, but its per cent was almost as high as that of the Rhode Island Reds. It is difficult to explain why hybrids show more broodiness than the more broody parent.

The hybrids from both crosses had an average egg size that was equal to that of the better of the two breeds used. The egg color of the hybrids was intermediate between the two parents, there being very little difference between the two crosses. As adults the two crosses were very similar and were intermediate in size between the two parental breeds. Thus it is seen that in all their qualities with exception of broodiness, they were practically equal or superior to the better of the two parents. This statement would not apply to size, but the hybrids were large enough to avoid any market discrimination.

Crosses Between the Single Comb White Leghorn, Single Comb Rhode Island Red, and Barred Plymouth Rock Breeds[7]

In this experiment all possible matings were made between Single Comb White Leghorns, Single Comb Rhode Island Reds, and Barred Plymouth Rocks. Reciprocal matings made between each pair together with the three groups of pure breds, made nine groups of chicks as follows: Single Comb Rhode Island Reds, Single Comb White Leghorns, Barred Plymouth Rocks, White Leghorn male by Rhode Island Red female, Rhode Island Red male by White Leghorn female, White Leghorn male by Barred Plymouth Rock female, Barred Plymouth Rock male by White Leghorn female, Rhode Island Red male by Barred Plymouth Rock female, and Barred Plymouth Rock male by Rhode Island Red female.

In so far as possible the experiment was planned so that the various groups of chicks to be compared had one parent in common. Since the colors of the offspring would not permit distinction between the pure-bred and crossbred clicks, not all comparisons could be made of related chicks. From the same groups of Rhode Island Red females it was possible to produce pure-bred Rhode Island Reds, Red-Leghorn hybrids, and Red-Rock hybrids. Throughout the period of the experiment, Rhode Island Red, White Leghorn, and Barred Plymouth Rock males were rotated every two days in this pen so that chicks of all three crosses were produced in each hatch. Hence the chicks from these three matings were half brothers and sisters. The chicks were identified by color, the pure Rhode Island Reds being red, the Red-Leghorns being white, and the Red-Rocks being black.

It was necessary to have two groups of Barred Plymouth Rock females, since it was impossible to distinguish between the pure Barred Plymouth Rock chicks and the males of the Rock-Red chicks. So from one group of females, pure Barred Plymouth Rock and Rock-Leghorn hybrids were produced, and from another the Rock-Red hybrids. Since all hybrids from White Leghorns are predominately white it was necessary to provide three groups of females from this breed. One group produced pure White Leghorns, another Leghorn-Reds, and the third, Leghorn-Rocks. The White Leghorn females were all from the same strain which had been fairly closely line bred.

By a system of rotation, the same White Leghorn males were used

7. For much of the data presented in this section the writer is indebted to W. P. Albright, who carried out the study of this phase of the problem as material for a master's thesis.

for producing all groups of chicks, that had a sire of this breed. The same was true of the males of the Barred Plymouth Rock and Rhode Island Red breeds. This method made the hybrids and pure breds as nearly comparable as they could be made in an experiment of this type.

Eggs were held for incubation during two ten-day periods, the second immediately following the first. All eggs were placed in the same incubator and, when hatched, all chicks of a hatch were kept in the same brooder house. In this way the effects of environmental factors were kept practically uniform for the groups compared. It was attempted to produce 50 chicks in each of the nine groups in each of the two hatches. However, with the influence of competitive fertilization and variability of egg production and hatchability, it was difficult to keep the size of the groups uniform.

Individual weights were taken at one day, at weekly intervals to the fourth week, and at biweekly intervals from the fourth to the tenth week, when the experiment was terminated.

TABLE VI.—GROWTH (IN GRAMS) OF PURE BREDS AND HYBRIDS IN PHASE 1 OF THE WHITE LEGHORN, RHODE ISLAND RED, AND BARRED PLYMOUTH ROCK CROSSES.

AGE.		1 day.	1 wk.	2 wks.	3 wks.	4 wks.	6 wks.	8 wks.	10 wks.
White Leghorns	♂	36.2	47.0	76.7	118.8	178.7	339.6	467.0	691.5
	♀	35.1	43.0	67.5	102.4	151.8	286.0	394.7	579.2
	Av.	35.7	45.0	72.1	110.6	165.3	312.8	430.9	635.4
Rhode Island Reds	♂	37.8	43.9	70.9	113.7	179.9	356.1	494.7	735.3
	♀	38.1	43.6	69.7	112.1	173.6	324.1	427.1	637.4
	Av.	38.0	43.8	70.3	112.6	176.8	340.1	460.9	686.4
Barred Plymouth Rocks	♂	29.8	34.5	55.3	89.8	141.5	286.5	393.0	591.5
	♀	29.3	34.5	56.2	88.0	134.0	261.9	364.0	565.0
	Av.	29.6	34.5	55.8	88.9	137.8	274.2	378.5	578.3
Leghorn ♂ × Red ♀	♂	37.9	49.0	82.1	130.0	195.0	372.3	522.5	784.4
	♀	36.6	44.8	72.8	113.0	171.1	312.0	424.1	630.2
	Av.	37.3	46.9	77.5	121.5	183.1	342.2	473.3	707.3
Leghorn ♂ × Rock ♀	♂	29.1	37.8	63.2	102.4	159.9	318.2	454.4	697.2
	♀	29.0	37.0	62.0	98.3	151.5	290.5	410.0	615.5
	Av.	29.1	37.4	62.6	100.4	155.7	304.4	432.2	656.4
Red ♂ × Leghorn ♀	♂	36.0	50.2	84.2	133.2	213.3	436.7	600.0	919.2
	♀	34.9	44.6	74.4	121.0	178.8	355.6	497.5	715.0
	Av.	35.5	47.4	79.3	127.1	196.1	396.2	548.8	817.1
Red ♂ × Rock ♀	♂	38.1	50.2	82.0	129.1	205.8	418.5	579.4	886.3
	♀	37.8	47.0	77.8	121.9	194.0	377.0	529.2	784.8
	Av.	38.0	48.6	79.9	125.5	199.9	397.8	554.3	835.6
Rock ♂ × Leghorn ♀	♂	36.9	47.2	77.9	123.9	187.7	367.7	506.2	775.5
	♀	36.7	44.2	70.8	108.2	160.5	298.2	411.5	604.0
	Av.	36.8	45.7	74.4	116.1	174.1	333.0	458.9	689.8
Rock ♂ × Red ♀	♂	38.2	48.1	79.9	126.1	197.5	389.8	537.7	818.0
	♀	36.8	43.8	72.9	112.5	174.8	339.8	465.7	706.1
	Av.	37.5	46.0	76.4	119.3	186.2	364.8	501.7	762.1

One factor entered to make two groups of chicks not exactly comparable with the others. This was the fact that all females used in the matings were beyond a year of age except one group of Barred Plymouth Rocks. These were pullets that had been in production only a short time, and from them were produced the pure Barred Plymouth Rocks and the hybrids from the cross of White Leghorn male by Barred Plymouth Rock females. The chicks from these females were handicapped by the small size of the eggs. Since the females used for producing the offspring compared in this study had been grouped for other studies, it was not possible to avoid the discrepancy in the one case, and the fact must be taken into consideration in the comparisons.

Although the relative growth was about the same in the two phases, the chicks of the second phase did not grow so rapidly as did the first. This difference could not be accounted for, since the chicks were hatched only ten days apart, fed the same ration, kept in adjoining rooms, and given as nearly the same treatment as was possible.

TABLE VII.—GROWTH (IN GRAMS) OF PURE BREDS AND HYBRIDS IN PHASE 2 OF THE WHITE LEGHORN, RHODE ISLAND RED, AND BARRED PLYMOUTH ROCK CROSSES.

AGE.		1 day.	1 wk.	2 wks.	3 wks.	4 wks.	6 wks.	8 wks.	10 wks.
White Leghorns	♂	35.4	46.2	67.8	104.3	162.9	285.3	460.2	674.1
	♀	34.2	40.4	59.6	90.3	132.7	242.1	382.1	554.7
	Av.	34.8	43.3	63.7	97.3	147.8	263.7	421.2	614.4
Rhode Island Reds	♂	33.6	39.6	59.9	95.7	158.2	305.3	494.8	727.0
	♀	34.3	39.7	61.1	96.3	154.3	281.8	443.8	645.3
	Av.	34.0	39.7	60.5	96.0	156.3	293.6	469.3	686.2
Barred Plymouth Rocks	♂	28.2	35.5	51.6	81.4	127.3	243.3	407.2	589.1
	♀	28.0	33.5	48.9	76.8	120.5	229.5	367.3	548.8
	Av.	28.1	34.5	50.3	79.1	123.9	236.4	387.3	569.0
Leghorn ♂ × Red ♀	♂	34.1	43.6	67.8	109.2	181.9	319.6	517.3	756.9
	♀	35.1	46.8	73.5	114.5	176.5	303.1	479.6	677.3
	Av.	34.6	45.2	70.7	111.9	179.2	311.4	498.5	717.1
Leghorn ♂ × Rock ♀	♂	28.3	35.7	51.1	81.4	126.7	252.9	421.4	642.1
	♀	26.7	34.8	53.0	84.9	135.2	245.9	394.5	574.5
	Av.	27.5	35.3	52.1	83.2	131.0	249.4	408.0	603.3
Red ♂ × Leghorn ♀	♂	35.2	45.2	67.0	103.8	171.8	311.0	500.0	753.0
	♀	33.3	44.1	70.4	112.4	180.0	324.1	506.8	707.7
	Av.	34.3	44.7	68.7	108.1	175.9	317.6	503.4	730.4
Red ♂ × Rock ♀	♂	37.5	45.8	71.8	111.7	183.8	341.9	552.5	812.8
	♀	34.0	43.6	67.0	105.1	171.4	306.3	494.8	714.5
	Av.	35.8	44.7	69.4	108.4	177.6	324.1	523.7	763.4
Rock ♂ × Leghorn ♀	♂	34.9	45.5	70.9	111.6	175.7	302.5	489.3	730.0
	♀	36.9	47.4	73.1	110.6	166.8	282.0	426.8	628.0
	Av.	35.9	46.5	72.0	111.1	171.3	292.3	458.1	679.0
Rock ♂ × Red ♀	♂	34.5	43.1	66.4	102.7	165.6	301.5	489.5	697.4
	♀	34.4	44.0	67.0	102.3	161.1	295.2	464.8	685.8
	Av.	34.5	43.6	66.7	102.5	163.4	298.4	477.2	691.6

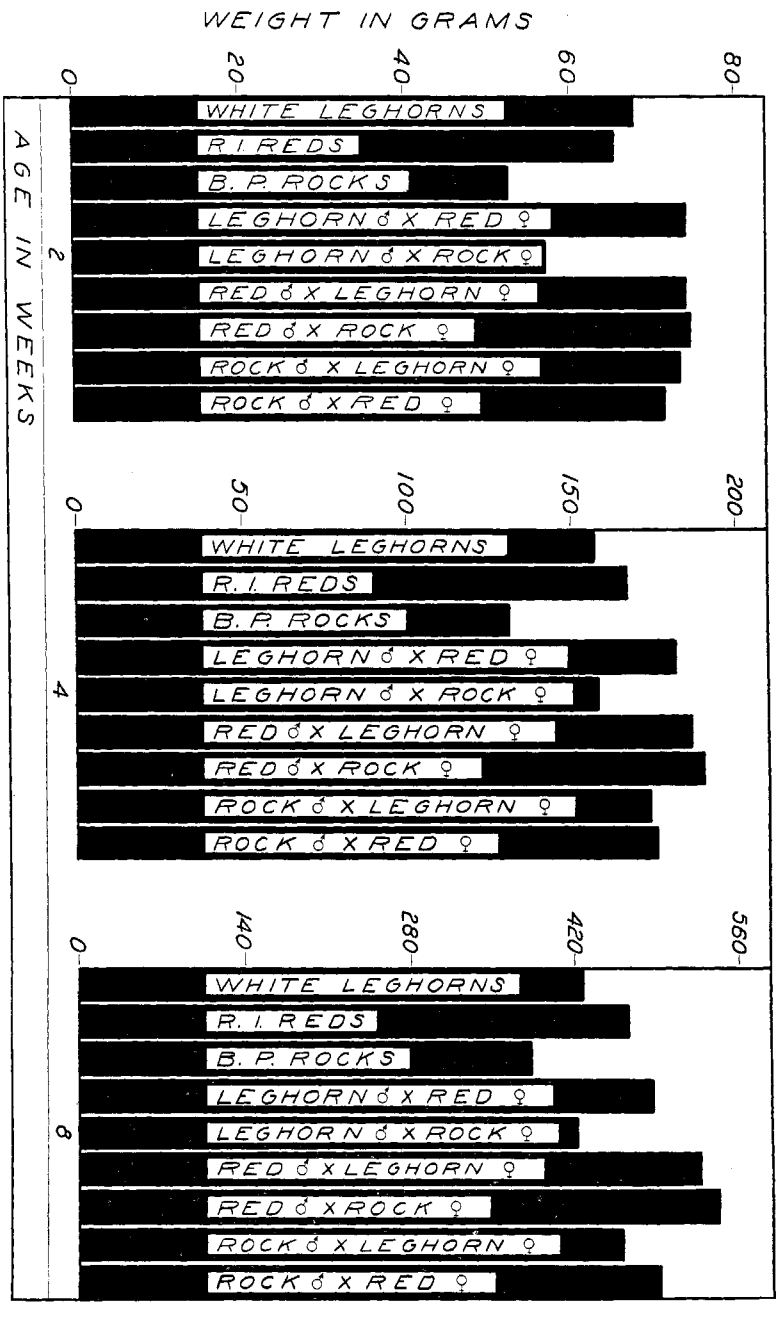

FIG. 6.—Comparison at various ages of hybrids from the crossing of White Leghorns, Rhode Island Reds, and Barred Plymouth Rocks, giving average of male and female averages.

WHITE LEGHORN-RHODE ISLAND RED CROSS

This cross is of interest because similar comparisons were made in a preceding section of this publication. Data were available for the comparison of rate of growth and chick mortality Table VI presents the data on growth for the first phase of the experiment and phase 2 is given in Table VII. The weights are given in grams and are the averages of the individual weights. Figure 6 presents graphically the average of the two phases at two, four, and eight weeks of age. Figure 7 compares the growth curves of pure White Leghorns and pure Rhode Island Reds with hybrids from their reciprocal matings. In both phases the hybrids from each cross outgrew the two pure breeds. In the first phase, one cross grew more rapidly while in the other its reciprocal was the better. Thus, it would appear that the direction of the cross is not important in so far as rate of growth is concerned. The weight of the Rhode Island Reds more nearly approaches that of the hybrids at 10 weeks of age but this is probably due to the fact that the Rhode Island Reds were larger than the hybrids at sexual maturity. The earlier sexual maturity of the hybrids was probably having a retarding effect at this age.

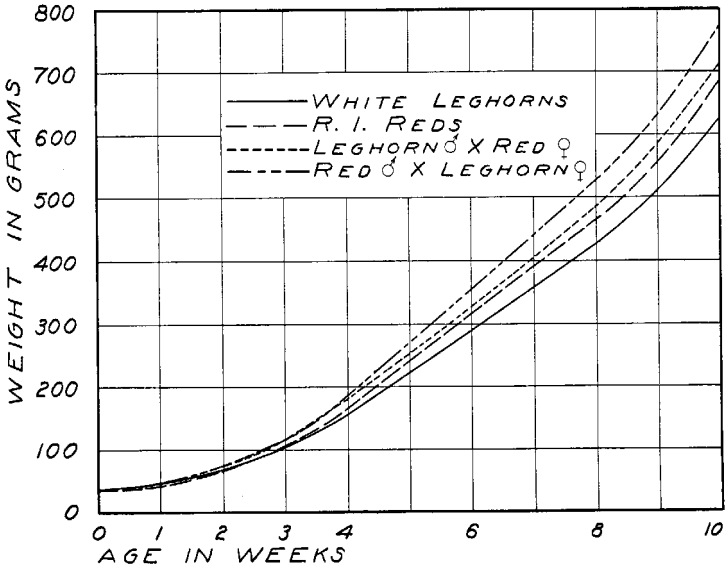

FIG. 7.—Comparison of growth of White Leghorns, Rhode Island Reds, and hybrids resulting from their crossing.

A summary of the chick mortality for the two phases is given in Table VIII. The per cent mortality is for the first three-week period. The White Leghorns had a mortality per cent of 9.9 and the Rhode Island Reds 14.9. Four per cent of the White Leghorn male by Rhode Island Red female cross died during the first three weeks, and of the reciprocal cross 6.3 per cent. The per cent of loss was relatively low in the two pure breeds, but the loss in the hybrids was still lower.

TABLE VIII.—CHICK MORTALITY IN VARIOUS GROUPS OF HYBRIDS, AND IN THE PURE BREEDS USED IN THEIR PRODUCTION.

	Phase 1.		Phase 2.		Per cent mortality, both phases.
	Total chicks.	Total mortality.	Total chicks.	Total mortality.	
White Leghorns	50	5	51	5	9.9
Rhode Island Reds	39	5	48	8	14.9
Barred Plymouth Rocks	66	12	51	11	19.7
Leghorn ♂ × Red ♀	47	1	28	2	4.0
Leghorn ♂ × Rock ♀	52	4	18	0	5.7
Red ♂ × Leghorn ♀	15	1	17	1	6.3
Red ♂ × Rock ♀	57	1	50	4	4.7
Rock ♂ × Leghorn ♀	66	5	48	0	4.4
Rock ♂ × Red ♀	55	2	48	4	5.8

WHITE LEGHORN-BARRED PLYMOUTH ROCK CROSS

This is the cross in which all groups were not exactly comparable, due to difference in size of the eggs from which the chicks were hatched. Here it was necessary to produce the pure Plymouth Rocks and the hybrids from the cross of White Leghorn male by Barred Plymouth Rock female from pullets, while the pure White Leghorns and hybrids from the mating of Barred Plymouth Rock male by the White Leghorn female were from larger hen eggs.

As is shown in Tables VI and VII, and figure 8, the cross of White Leghorn male by Barred Plymouth Rock female had a growth rate very similar to that of the pure White Leghorns and at some points in the graph was below the pure breds. It has already been explained that these two are not exactly comparable. The best group was from the cross of Barred Plymouth Rock male by White Leghorn females. The Barred Plymouth Rock had very slow growth, which during the early stages was probably retarded by

the size of the egg from which the chick hatched. The more reliable comparisons in this cross are between the Barred Plymouth Rocks and hybrids from the White Leghorn male by Barred Plymouth Rock females, and between the pure White Leghorns and progeny from the cross of Barred Plymouth Rock male by White Leghorn females. In these comparisons the hybrids consistently outgrew the pure breds.

The chick mortality given in Table VIII again shows the losses among hybrids to be less than that in either pure-bred group. The

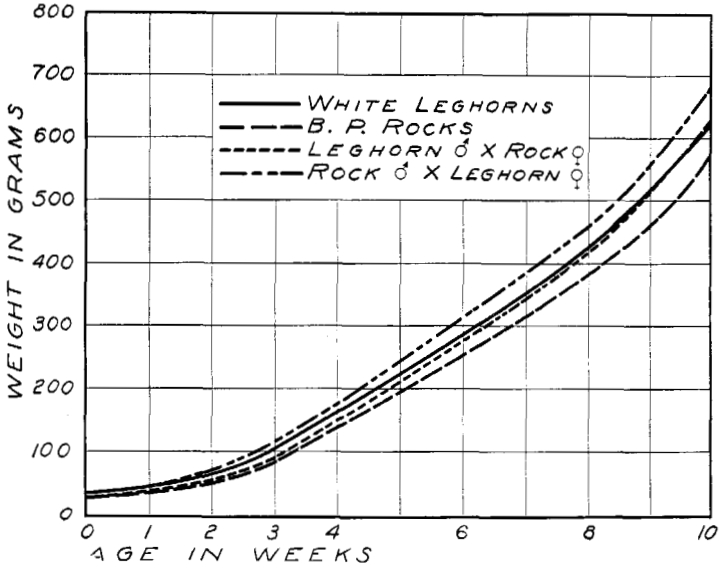

FIG. 8.—Comparison of growth of White Leghorns, Barred Plymouth Rocks, and hybrids resulting from their crossing.

White Leghorns had a mortality per cent of 9.9; the Barred Plymouth Rocks, 19.7; White Leghorn male by Barred Plymouth Rock female, 5.7; and Barred Plymouth Rock male by White Leghorn female, 4.4.

RHODE ISLAND RED-BARRED PLYMOUTH ROCK CROSS

Again in this cross it is probably not entirely correct to compare the Barred Plymouth Rock chicks coming from pullets with the other three groups which were the offspring of hens. Figure 9 and Tables VI and VII show the Rhode Island Reds to have considerably outgrown the Barred Plymouth Rocks. However, each group of hybrids from their crossing grew more rapidly than the Rhode Island Reds.

The per cents of mortality in these crosses were as follows: Rhode Island Red, 14.9; Barred Plymouth Rock, 19.7; Rhode Island Red male by Barred Plymouth Rock female, 4.7; and Barred Plymouth Rock male by Rhode Island Red female, 5.8.

COMPARISON OF ALL CROSSES

Figure 6 graphically presents a comparison of all crosses and the three pure breeds. The columns represent the average of the averages for the two phases. The average for each phase was the average of

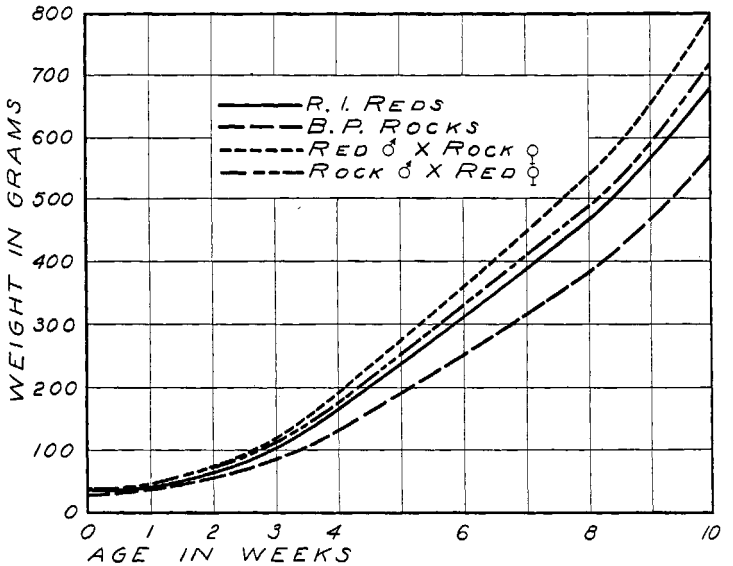

FIG. 9.—Comparison of growth of Rhode Island Reds, Barred Plymouth Rocks, and hybrids resulting from their crossing.

the male and female averages at each age. Comparisons are made at three different ages, two, four, and eight weeks. The relative positions were not always the same for the three points on the growth curve. A factor which should be taken into consideration here, especially in weight comparisons at early ages, is the size of the egg from which the chick hatched. Individual egg weights are not available, but we do have the weight at hatching which has been found to be closely correlated with egg size. Only in two matings did the day-old size differ greatly from the average, these being the Barred Plymouth Rocks and offspring of White Leghorn male by Barred Plymouth Rock females. These two groups had the same dams.

The cross of Rhode Island Red male by Barred Plymouth Rock females produced hybrids that led all others at all ages. The cross which ranked second was the Rhode Island Red male by White Leghorn female. The reciprocals of these two matings were also among the more rapidly growing groups. Except for the mating of the White Leghorn male by the Barred Plymouth Rock pullets, the three pure breeds were at the bottom of the list. The ranking with respect to chick mortality also showed the three pure breeds to have the highest mortality.

Probably the most crucial test for the effects of hybridization on vigor is found in the three groups of offspring from the Rhode Island Red females. Three groups of males (Rhode Island Reds, White Leghorns, and Barred Plymouth Rocks) were rotated at two-day intervals on this same group of females. The pure Rhode Island Red, Rhode Island Red-White Leghorn hybrids, and Rhode Island Red-Barred Plymouth Rock hybrids were hatched at the same time from the same hens' eggs. At practically all ages the hybrids were larger than the Rhode Island Reds although the Rhode Island Red chicks made a very good growth. The mortality among the pure Rhode Island Reds was also much higher than in either group of hybrids.

A similar comparison was made of the progeny of the Barred Plymouth Rock pullets which produced much less vigorous pure breds. The Barred Plymouth Rock chicks here showed very slow growth and high mortality while their hybrid half brothers and sisters by the White Leghorn sire were much more vigorous. These hybrids were, however, the least vigorous of the six groups of hybrids. This would indicate that although the hybrids have been rather consistently more vigorous than the pure breeds producing them, the vigor of the pure breeds themselves is reflected in their hybrids.

General Discussion

The results of crosses between the White Leghorn breed and Jersey Black Giants, Rhode Island Reds, and Barred Plymouth Rocks have been reported upon. Matings between the Barred Plymouth Rocks and Rhode Island Reds were also considered. In each case an attempt was made to obtain an accurate comparison with the pure breeds involved. In all crosses comparisons were made of chick growth and mortality, and in some crosses hatchability and egg production were also considered. In practically all instances the hybrids were found superior. Sometimes the differences were slight,

but the consistent superiority at each step in the process of production means an accumulative economy. A small per cent improvement in the hatch, together with a small reduction in the chick mortality, plus a small increase in the production of the individual females, contribute to a material reduction in the cost of the resulting egg. In some comparisons the improvement from hybridization was a very material one. To the other advantages already mentioned should be added that of being able to identify the sexes at hatching, which is discussed more fully in another section of this bulletin.

The color of the egg of the hybrid is probably its most serious handicap, since it varies from slightly tinted to well-colored. This, however, would be important only in sections where egg color is well standardized. The increase in broodiness observed in the Rhode Island Red-White Leghorn cross would also be undesirable if it be characteristic of hybrids, but there is not yet sufficient information to determine whether this be true.

Although this study has considered most of the more popular breeds and varieties, there is need for investigation of others, since it is probable that different combinations will yield widely differing results.

Cross of Strains of the Same Breed

It has been suggested that the apparent stimulation resulting from the crossing of two breeds or varieties adds nothing to the vigor of the breed, but merely restores vigor which is lost through inbreeding. If this be true, then from the mating of two distinctly related strains of the same breed a stimulation similar to that from crossing breeds should result. Since all types of the domestic fowl are probably related, the difference between breed and strain crosses is one of degree.

In order to check upon the effect of crossing two strains of the same breed, the flock of production-bred Single Comb White Leghorns of the Kansas Agricultural Experiment Station were mated to a well-known West Coast production-bred strain of the same breed. There had been no crossing of the two strains as far back as records were available, and for a period of eight generations the pedigrees showed no evidence of any common ancestors. Since the two strains were carried in widely separated sections of the country, it is probable that their independent history goes back considerably beyond the available records.

For the production of the individuals being compared, eight breed-

ing pens were arranged. Four of the pens were headed by males of the Kansas strain and four by those of the West Coast strain. In each pen there were ten pullets equally divided between the two strains. By this arrangement it was possible to compare half brother and sister, pure and cross-strain chicks from each male used.

The criteria of vigor used were hatchability, chick mortality, rate of growth, and egg production. Table IX presents the comparison of the vigor of the two strains with the offspring resulting from their crossing.

TABLE IX.—SUMMARY OF THE RESULTS OF CROSSING TWO STRAINS OF WHITE LEGHORNS.

	Kansas Leghorns.	W. Coast Leghorns.	Kansas ♂ × W. Coast ♀.	W. Coast ♂ × Kansas ♀.
Per cent hatchability	75.4	72.4	75.3	84.2
Per cent chick mortality (to 3 weeks)	5.6	2.4	2.7	3.5
8-week weight in grams (average of ♂ and ♀ average)	422.1	465.8	420.2	467.0
Winter egg production	76.0	79.6	90.0	91.0

HATCHABILITY

The hatchability results are from 2,441 eggs produced by the four groups of females during the eight-week period. Eggs were set at weekly intervals and were held and incubated under identical conditions. In the same trays were placed eggs from the four groups of females. The incubation results are given in Table X. The per cents of hatch given are for fertile eggs only. The Kansas females gave slightly better hatchability than did the West Coast birds, but the females from the same strain mated to West Coast males produced eggs which hatched must better than those of any other mating. The cross of Kansas male by West Coast females had a hatchability per cent very similar to the two pure strains.

TABLE X.—HATCHABILITY RESULTS FROM CROSSING TWO STRAINS OF WHITE LEGHORNS.

	Number females.	Number eggs.	Number infertile.	Per cent hatch of fertile eggs.
Kansas Leghorns	16	556	27	75.4
West Coast Leghorns	17	545	42	72.4
Kansas ♂ × W. Coast ♀	19	667	63	75.3
W. Coast ♂ × Kansas ♀	20	673	29	84.2

CHICK MORTALITY

As in other comparisons the chick mortality was for the first three-week period. Chicks from all groups in the weekly hatches were kept in the same brooder house, one being allotted to each hatch. Accidental mortality was excluded. The per cent of mortality for all groups was relatively low. The West Coast strain had a mortality per cent of 2.4, which was the lowest of the four groups being compared. The Kansas strain had the highest per cent, which was 5.6. The two strain crosses were intermediate, being 2.7 and 3.5.

RATE OF GROWTH

The rate-of-growth data were taken as described in the Rhode Island Red and White Leghorn cross. The 1,708 chicks considered were distributed as follows: Kansas strain, 382; West Coast strain, 354; Kansas male by West Coast female, 439; and West Coast male by Kansas female, 533. The comparison given in Table IX is the average of the male and female average weights at eight weeks of age. The complete data for all weights taken to eight weeks of age are presented in Table XI and the same data are in graphic form in figure 10. At all ages, the West Coast strain chicks and those from the cross of West Coast males by females from the Kansas strain had almost identical weights. The average weights for the Kansas strain and the offspring of Kansas males by West Coast females were also very similar. Although the difference between reciprocal crosses is significant, no satisfactory explanation was found.

Individual weights taken in grams on the females at 12 and 16 weeks and recorded in the following order — Kansas, West Coast,

TABLE XI.—GROWTH OF CHICKS IN TWO STRAINS OF WHITE LEGHORNS IN COMPARISON WITH THOSE RESULTING FROM THEIR CROSSING.

	Kansas Leghorns.	W. Coast Leghorns.	Kansas ♂ × W. Coast ♀.	W. Coast ♂ × Kansas ♀.
Number of chicks.	382	354	439	533
Age.				
1 day	36.3	34.9	35.3	36.4
2 weeks	65.7	74.8	65.7	74.1
4 weeks	142.8	161.4	142.4	160.6
6 weeks	279.7	307.4	277.5	308.4
8 weeks	422.1	465.8	420.2	467.0

Kansas male by West Coast female, West Coast male by Kansas female were at 12 weeks: 665.0, 741.8, 696.7, and 732.8; at 16 weeks, 922.5, 1,022.3, 983.0, and 1,011.7. It is seen that the cross of the West Coast male by Kansas female is dropping below the weights of the West Coast strain that it equaled at earlier ages. On the contrary, the reciprocal cross is gaining on the Kansas strain that equaled it in earlier ages. These changes in position are probably due to the effects of the size at sexual maturity.

At the time of laying the first egg, the West Coast strain pullets averaged 1,566 grams in weight and the Kansas strain females, 1,446

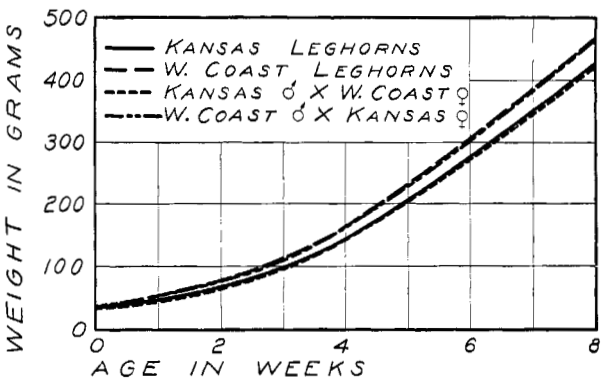

FIG. 10.—A comparison of the growth of the chicks of two strains of White Leghorns and those resulting from crossing the two strains.

grams. The cross of West Coast male by Kansas female weighed 1,472 grams and its reciprocal 1,499 grams, hence the females from the two crosses were, at sexual maturity, intermediate in weight between the two strains being crossed.

EGG PRODUCTION

Complete data on egg production were not available, due to the fact that pullets of these matings are still in their first year of production. Records for the winter period (to March 1) are available, and since this period of production has usually been found to be closely correlated with the first year's total production the results are here presented. The 377 pullets were distributed as follows: Kansas strain, 73; West Coast strain, 101; West Coast male by Kansas female, 100; Kansas male by West Coast female, 103. The pullets being compared for egg production were kept in two 20- by 40-foot straw-loft laying houses which were identical in

construction and located closely together. The four groups of pullets were equally represented in each house. The records were started at the date of first egg for each female. The West Coast strain had an average production of 79.6 eggs and the Kansas strain 76 eggs. The females from reciprocal crosses between the two strains had almost identical production being 91 and 90.9.

The results would indicate that egg production was improved by crossing the strains. The age at first egg, which materially influences the production of the winter period, was also taken into consideration. The two pure strains had exactly the same average age at first egg, 167 days, while the two strain crosses matured slightly younger, 162.0 and 161.6 days. The difference in age at sexual maturity will not account for the difference in egg production between the pure strains and the strain crosses, so that factors such as intensity of production and winter pause must have contributed.

SUMMARY

When all criteria of vigor are considered, it cannot be said that the stimulation from crossing is as evident as in the breed crosses already presented. The cross of West Coast male by Kansas females was best in hatchability and egg production. The West Coast strain had the lowest chick mortality and a weight at eight weeks practically equal to the best hybrid group. When all factors are considered, it can be said that the best results were from the cross of West Coast male by Kansas females, since it was superior in hatchability, egg production, and weight at eight weeks. Its chick mortality was also only slightly above the West Coast strain.

DISTINGUISHING SEX AT HATCHING

The need of a method of identifying the sexes of poultry at hatching has long been felt. In most other animals there are external characteristics that make the sexes readily distinguishable. However, in the bird there are no dependable marks for sex until it is at least a few weeks old. With the development of the hatchery industry, this need has been emphasized. With the specialization in the industry, there is a demand for chicks of one sex. This demand is partially being met by started chicks made possible by the storage brooder, but this equipment can never more than partially meet the need. If the poultryman who buys chicks primarily for replenishing his supply of layers can be guaranteed 100 per cent females, his facilities for brooding may be reduced by half. In certain regions

during the late season the males are reared at a loss, so that it would be more profitable to kill them at hatchings. The broiler industry is becoming an important phase of poultry husbandry, and since it is an established fact that males grow more rapidly than females they are preferred for broiler production.

The Barred Plymouth Rock breed is the only standard breed in which the sexes may be distinguished with any high degree of accuracy. Chicks of this breed are largely black above except for a light spot on top of the head. The spots on the heads of the males average slightly larger than those of the females, so that if a group of chicks is divided in halves, placing the chicks with large head spots in one group and those with small ones in another, it will be found that the sexes have been separated with a fair degree of accuracy. The legs of the females have a darker average color than those of the males, so increased accuracy in classification of the sexes will be obtained if this factor is taken into consideration in placing questionable chicks. It is desired, however, that methods applicable to other breeds be found.

Prof. R. C. Punnett, of Cambridge University, England, has recently described[8] a new breed, the Cambar, in which the sexes may be identified at hatching by means of down color. This new type was originated from crossing of the Barred Plymouth Rock and Gold Campine. As yet nothing is known of the economic qualities of this breed, and it is not yet available to the practical poultryman.

Professor Punnett in 1919[9] first suggested a method whereby the sexes of certain crossbred chicks might be identified at hatching by means of color. This was found possible, due to the fact that certain characteristics of poultry follow a peculiar type of inheritance known as crisscross inheritance. This mode of inheritance results only when the cross is made one way and produces daughters that resemble the sire's down color and the sons that have the dam's down color. The term sex-linked inheritance is also applied to such cases.

SEX-LINKED INHERITANCE

There are four well-known characteristics of poultry that exhibit the sex-linked type of inheritance. These are the gold and silver color, barring and black, slate and yellow shank color, and early and late chick feathering. The use of sex-linked crosses has become rather widespread in England, and chick color has been the

8. Punnett, R. C., and Pease, M. A. Genetic studies in poultry. VIII. On a case of sex-linkage within a breed. Jour. Genetics 22:395-397.

9. Punnett, R. C. Jour. Bd. Agr. (London).

basis of sex identification, Shank color is not sufficiently well developed at hatching to identify sex by this means. Since the classification of early and late feathering has been based upon the appearance of the tail feathers, which do not show until the chick is about a week old, this character was also of no use in distinguishing sex at hatching.

To give an example of sex-linked inheritance, if a Rhode Island Red male is mated to a light Brahma female, the female chicks will show various shades of buff- or red-colored down and the male chicks will be white or smoky white, being very similar to the chicks of standardbred Light Brahmas. This is a case of crisscross inheritance where the daughters show the down color of the father and the sons that of the mother. As adults the females are buff or red in color and the males will be much like pure Light Brahmas. If the cross is made in the opposite direction, using the light Brahma male, the chicks will all resemble pure Light Brahmas and the sexes cannot be identified at hatching.

GOLD-SILVER CROSS

Among the common breeds and varieties that carry the gold factor and may be used as the sire in a cross are all buff varieties, partridge pattern, gold laced, Brown Leghorn, and Rhode Island Red. The breeds and varieties from which the females for a cross may be chosen include all silvers, all Columbian varieties, Light Brahmas, and White Wyandottes. Any cross of a male from the gold group by a female from the silver group produces offspring that show a different color pattern in the two sexes. (Fig. 11.) The gold females can be much more easily distinguished from the silver males if the Columbian pattern is involved. (Fig. 12.) The breeds and varieties carrying this pattern are all buffs, Rhode Island Reds, Columbians, and Light Brahmas. It does not matter from which side this pattern enters the cross, but since it is what is referred to as a dominant character, most of the offspring will show its pattern. Chicks from such a cross have very little pattern in the down and allow the difference between the gold and silver to exhibit itself. As adults the males will show the Columbian pattern and the females will be buffs or reds. Where the Brown Leghorn male is crossed to laced or penciled varieties, the broad brown down stripe covers so much of the crossbred chick's back that the golds and silvers are not so easily distinguished.

The most serious handicap to the use of the gold-silver cross is that there are relatively few production-bred silver varieties in

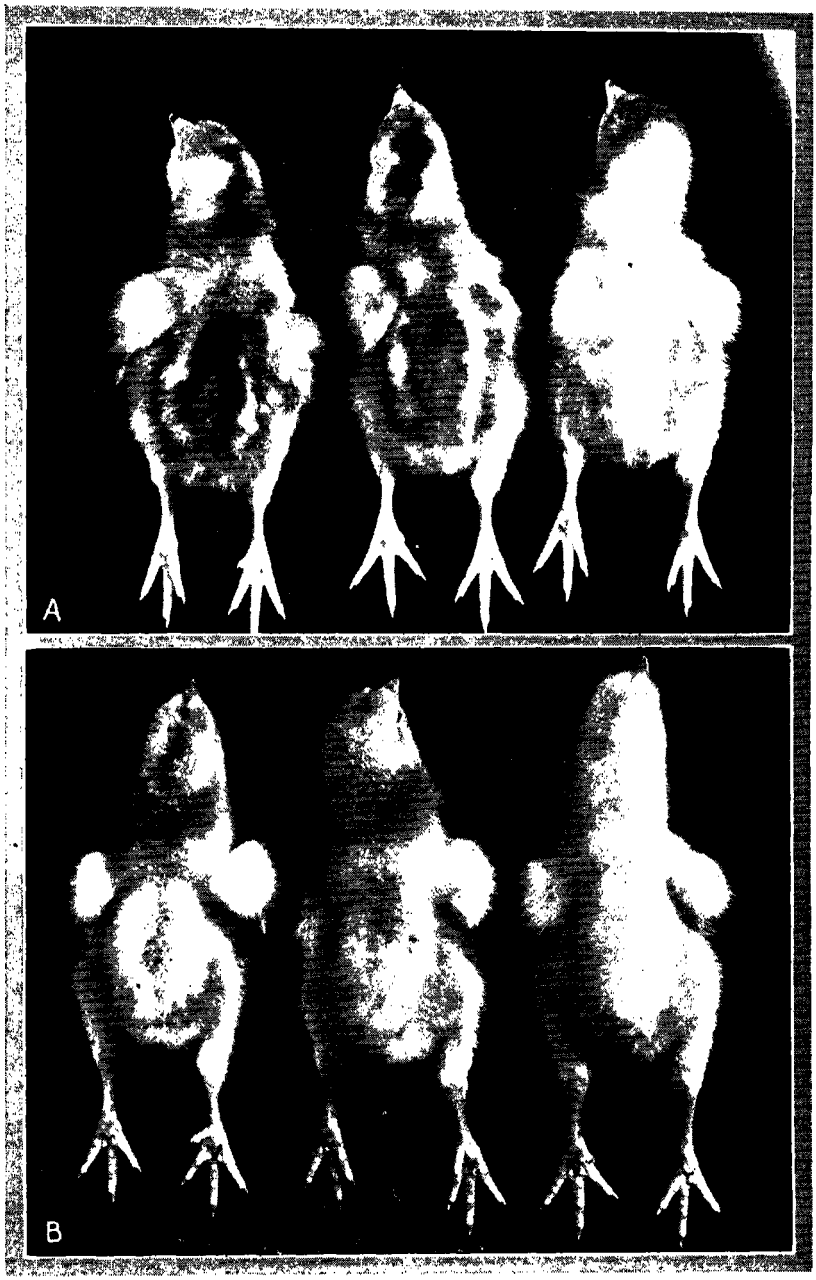

FIG. 11.—Male and female chicks from the cross of Rhode Island Red male by White Wyandotte female. (A) Chicks showing female colors ranging from a definitely brown-striped chick to one showing only a light tint of buff. (B) Male chicks, white or yellowish in color but never showing buff or red. Some males show smokiness in the down, especially on the neck or head.

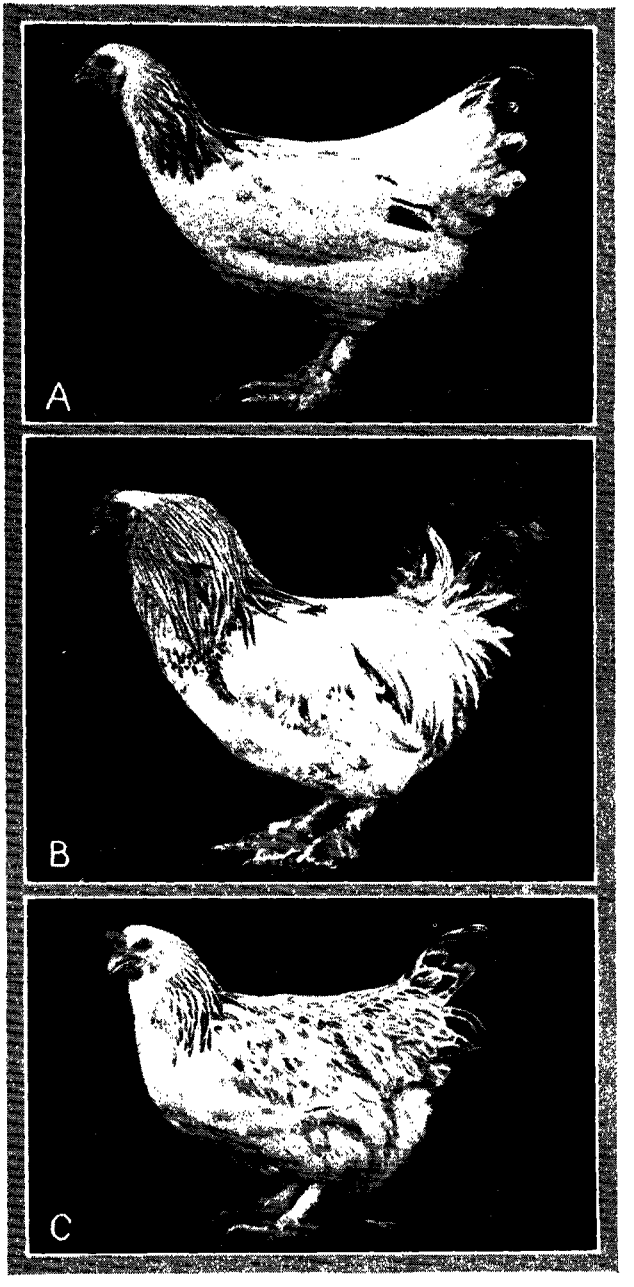

FIG. 12.—Some first-generation crossbreds where the Columbian pattern is involved. This pattern is practically dominant to most particolor patterns. (A) A hybrid female from the cross of Light Brahma male by Silver Laced Wyandotte female. (B) A hybrid male from the cross of Brown Leghorn male by Light Brahma female. (C) A female off-

spring from the cross of light Brahma male by Brown Leghorn female.

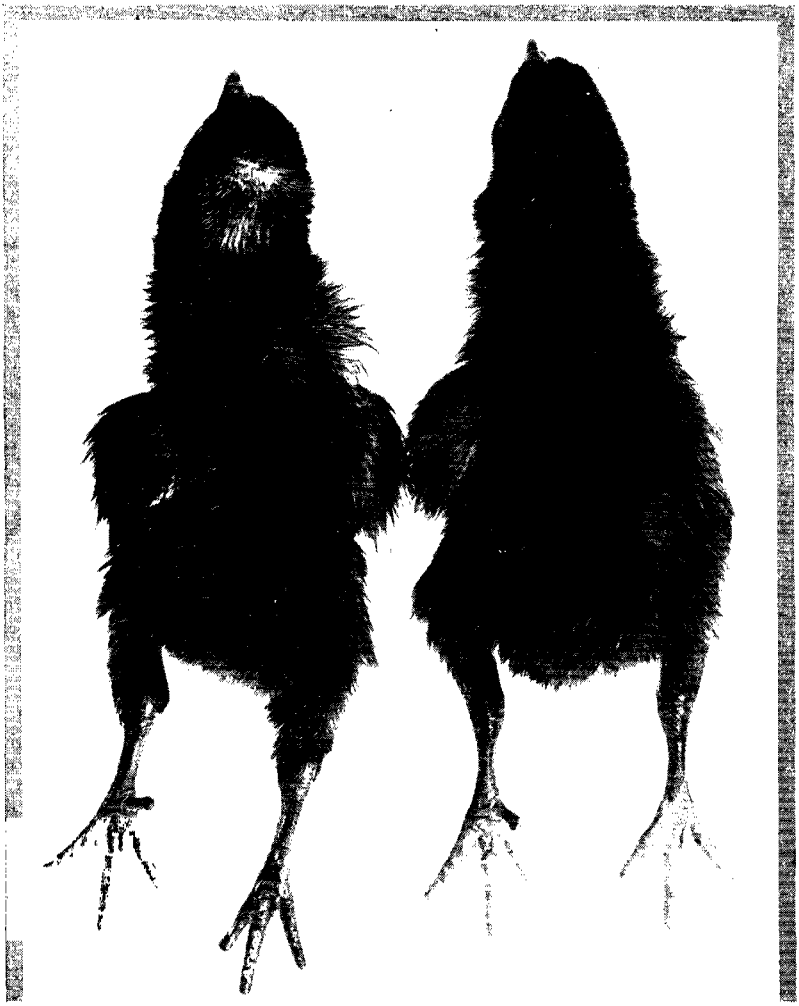

FIG. 13.—Hybrid chicks from the cross of the Rhode Island Red male by Barred Plymouth Rock female. Left, male chick, showing light head spot. Right, female chick which is entirely black on head and back.

America and the silver varieties are not especially popular. On the male side we have the Rhode Island Red, the Brown Leghorn, and all buff varieties, which supply an abundance of well-bred birds of the one sex. The White Wyandotte, although in the white group, is a recessive white and has usually been found to carry silver. Difficulty arises, however, from the fact, that the white plumage makes it impossible to detect the individuals that do not carry silver. Some White Wyandottes also carry black and will throw many black chicks the sex of which cannot be determined. Although these difficulties may be encountered in using the White Wyandotte breed as a silver, it is here listed because of its availability and production qualities. Many strains of this breed when crossed to gold males will give good crisscross inheritance, and when satisfactory strains can be found the White Wyandotte probably will produce better hybrids than most other silver breeds in America.

Barred Plymouth Rocks, White Plymouth Rocks, Blacks, and White Leghorns cannot be used in this cross because of the masking effects of the patterns carried by these breeds upon the gold and silver colors.

BARRED-NONBARRED CROSS

The cross which has been used more extensively than any other in this country is the one in which the presence or absence of the factor for barring has been the distinguishing feature. If Barred Plymouth Rock females or the females of any breed showing the Dominique pattern are mated to blacks or any breed showing other patterns, the female chicks are uniformly black or brownish black above and the males are black with a prominent light spot on top of the head. (Fig. 13.) This head spot makes it possible to separate the sexes. As adults the males will be barred and the females predominately black. (Fig. 14.) Some white variety males may be used, but the White Wyandotte is the only one that the writer's experience would indicate may be safely used. Neither the White Leghorn nor the White Plymouth Rock male may be used, since the former will give all whites and the latter will yield only barred offspring. If black males are used, the female offspring will be uniformly black, but where the sire comes from breeds showing other patterns the daughters may show some silver or gold, usually on the breast.

The Rhode Island Red male by Barred Plymouth Rock female is the cross most frequently used in this country, since they constitute two of our most widely distributed production-bred dual-

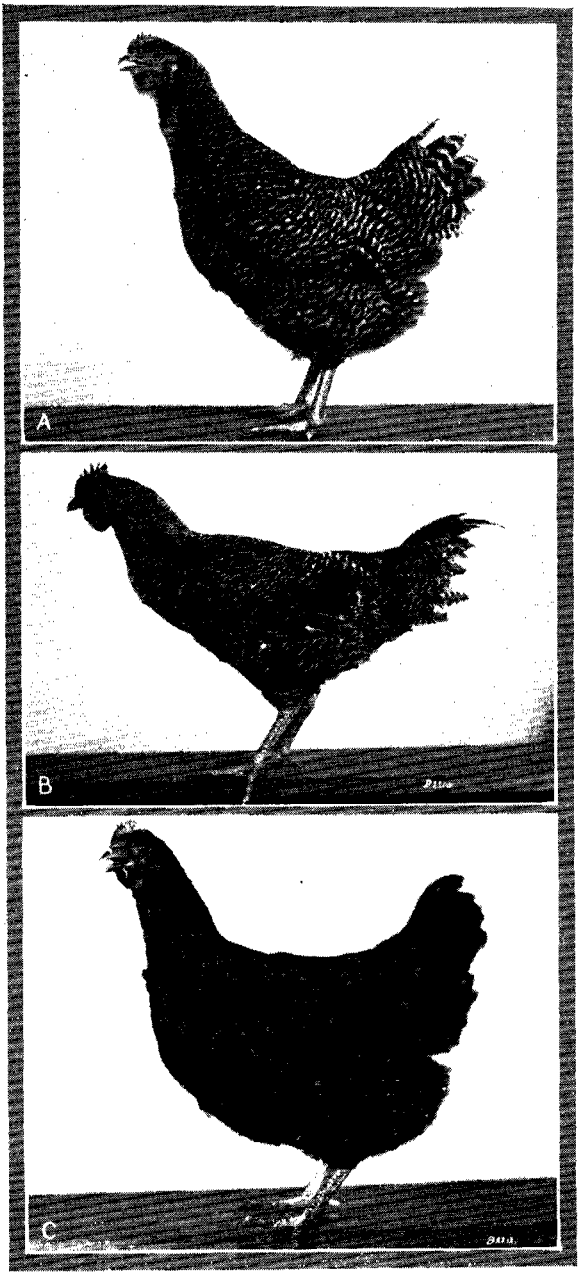

FIG. 14.—First-generation hybrids from the cross of Rhode Island Reds by Barred Plymouth Rocks. (A) A barred female from the cross of Barred Plymouth Rock male by Rhode Island Red female. In this cross the males are also barred. (B) A brother of female C. (C) A black female from the cross of Rhode Island Red male by Barred Plymouth Rock female.

purpose breeds. There are, however, other breeds which might be used with as good success. Both the Black Minorca and Ancona should produce good crossbreds the sexes of which could be identified. The Australorp is another high-producing breed from which the male could be obtained for crossing on the Barred Plymouth Rock female. The last three mentioned will give more uniform-colored hybrids than the cross utilizing the Rhode Island Red.

TABLE XII.—A LIST OF THE MORE COMMON BREEDS AND VARIETIES THAT MAY BE USED IN THE VARIOUS CROSSES FOR DISTINGUISHING SEX AT HATCHING.

(Only the more easily distinguished crosses are given.)

Cross.		Type of chick.	Type of adult.
Male.	Female.		
Gold-Silver Cross.			
1. Rhode Island Red.	White Wyandotte. Silver Penciled Rock. Silver Penciled Wyandotte. Silver Laced Wyandotte. Columbian Rock. Columbian Wyandotte. Dark Brahma. Light Brahma.	Females buff or red color. Males cream or white; may show smokiness in down. Both sexes may show narrow striping.	Females buff to red; may show some stripping or striping. Males Columbian pattern.
2. Buff Varieties: Buff Leghorn. Buff Minorca. Buff Plymouth Rock. Buff Wyandotte. Buff Cochin.	Same as No. 1.	Same as No. 1 except female chicks generally lighter in color.	Same as No. 1 except females usually buff.
3. Brown Leghorn. Partridge Rock. Partridge Wyandotte. Golden Laced Wyand'te.	Columbian Rock. Columbian Wyandotte. Light Brahma.	Same as No. 1.	Same as No. 1.
Barred-Nonbarred Cross.			
4. Blacks.	Barred Plymouth Rock.	Females all black above. Male black above except white spot on head.	Females black. Males barred.
5. All other color varieties except White. White Wyandotte may be used.	Barred Plymouth Rock.	Same as No. 4.	Same as No. 4 except females may show some gold stippling or striping on breast.
Rate-of-Feathering Cross.			
6. White Leghorn or practically any Mediterranean breed.	All American, Asiatic, and Orpington breeds.	Females have well developed wing feathers at hatching. Males show none or very short feathers.	Difference in feathering not shown in adult.

Note.—Certain European breeds could have been included, but due to their restricted availability were omitted.

CHOICE OF BREEDS FOR PRODUCTION OF CROSSBREDS

In choosing breeds for the production of crossbreds a number of factors should be taken into consideration. A primary consideration is the ease with which the sexes may be distinguished. (Table XII.) It has already been mentioned that in the gold-silver cross, if the hybrid has the distinct brown down stripe characteristic of the chick of one of the parents, the gold and silver ground colors may be obscured. If one of the breeds carries the Columbian pattern, this difficulty will usually be avoided.

Another important factor is the adult color of the crossbreds. One of the most serious drawbacks to the utilization of crossbreds in America is the fact that the most feasible cross, the Rhode Island Red male by Barred Plymouth Rock females, produces black daughters. The market discrimination against black birds detracts from the popularity of this cross.

If the crossbred females are to be retained as layers, the production tendencies of the breeds involved is a matter that should be considered. It appears logical that the breeds and varieties in which attention has been given to production breeding should yield better producing crossbreds. It is unfortunate that the most popular egg breed, the Single Comb White Leghorn, cannot be used in crosses where color is the basis for distinguishing sexes at hatching.

To the breeder who wishes to maintain a particular type, crosses within the breed make an appeal. In England there are available varieties that make this possible. One of the most successful crosses of this type is the one using the Black Leghorn male and the Cuckoo Leghorn female. Other varietal crosses used there are Gold and Silver Campines, Gold and Silver Penciled Hamburgs. Most of these varieties are not readily available in America. There are, however, a few available crosses between varieties of the same breed. Barred Plymouth Rock females may be mated to practically all other varieties of Plymouth Rocks excepting the White. Buff Plymouth Rock males may be used with Silver Penciled, Partridge, or Columbian varieties for the production of gold and silver chicks. The Silver Laced and Golden Laced Wyandottes offer a possibility. Buff Wyandotte males may be mated to any other variety of Wyandottes showing silver, including the White. It is true, however, if opinion may be based on the hybridization of plants, that varietal crosses probably will not give the maximum stimulation and that the mating of more divergent types will give the greatest vigor. Not enough work has yet been done to make it possible to state whether this relationship holds true with animals.

DEVELOPMENT OF WING FEATHERS AS A MEANS OF DISTINGUISHING SEX AT HATCHING

During the course of studies made at the Kansas Agricultural Experiment Station a number of breeds and varieties of poultry have been observed for rate of chick feathering. Most of the more common breeds and varieties fall into two groups, the early- and the late-feathering. The terms early and late refer to the age at which the adult type of plumage begins to replace the chick down. The primary and secondary wing feathers are the first to develop, being visible in some breeds at hatchings. In studies of rate of feathering the age at which tail feathers appear has been found to be the most definite basis of classification. In early-feathering breeds the tail feathers appear at from six to eight days of age, and in late-feathering ones these feathers do not appear before the twentieth day. The term late-feathering is not here used to apply to the extremely late-feathering characteristic of Barred Plymouth Rocks but only as contrasted with the very early feathering of the Mediterranean breeds. This extremely late-feathering is due to other genetic or physiological factors. Observations have shown that the early-feathering is confined to the Mediterranean class of fowls. Late-feathering has been found in most other breeds. It is true, however, that some breeds of the American class throw varying per cents of early-feathering chicks. In most cases the exceptions occur rather infrequently.

Studies by the writer[10] and others have shown the differences in rate of feathering belong to the sex-linked group and show the criscross inheritance. If an early-feathering male is mated to a late-feathering female, the daughters are early-feathering and the sons are late-feathering. If the cross is made using the male of the late-feathering breed, all chicks are late-feathering. From the cross using the early-feathering male the sexes may be accurately identified by the presence or absence of tail feathers at ten days of age.

A study of newly hatched chicks in crosses involving rate of feathering has also shown that the sexes may be distinguished with a high degree of accuracy. Identification is made by means of the growth of the primary and secondary wing feathers. For most accurate separation the examination should be made as soon as most of the chicks are fluffed out. If the inspection is delayed there may be some difficulty in separating the earliest hatched males from the

10. Warren, D. C. Inheritance of rate of feathering in poultry. Jour. Heredity 16:13-18. 1925.

latest hatched females. The comparison of male and female wing feathering shown in figure 15 is for chicks taken from the incubator when the hatch was just completed. The wings shown are from crossbred chicks in the mating of the White Leghorn male on Rhode Island Red females. The right-hand row of wings are from females and the other row from males. The female wing feathers are much longer than those of the males. The ends of the rows of wings show the most extreme conditions for each sex. It is seen that in the example of the most advanced development in the male, the flight feathers are scarcely visible beyond the down, while the female having the least development shows them very conspicuously. The photograph in figure 16 was taken from the under side of the wing, from which view the development of the flight feathers may be best seen. If there is a delay in making the examination, consideration should be taken of the fact, and in this case the most advanced males will have wing feathers similar to the least advanced females in figure 15, while most of the females will have distinctly longer wing feathers.

If there is a question about one's judgment in separating the sexes, a few autopsies may be made in questionable cases to check upon accuracy. The testes and ovaries are plainly visible in a newly hatched chick. Figure 17B shows the incision to be made for examining the sex organs of a newly hatched chick. The cut is most easily made with a small pair of scissors. The incision is made through the ends of the ribs on one side, across the back and through the ribs on the opposite side. The section of the back included in the cut may then be lifted, exposing the internal organs. When making the incision the point of the under blade should be kept in contact with the wall of the abdominal cavity so as to avoid rupturing the yolk sac which has not yet been absorbed. If ruptured, the yolk will be freed in the cavity and obscure the organs. If the yolk sac and digestive organs are pushed aside, the sex organs may be seen on the wall of the back just above the gizzard.

As is shown in figure 17A, the male sex glands are paired, elongated, ovoid organs, usually creamy white in color. At this stage the ovary (fig. 17C) may be seen on the left side only. Sometimes there may be a trace of a right ovary, but the female organ is differentiated from the testis by its more flattened leaf shape. If the incision is made immediately after killing, the vision may be obscured by hemorrhages, but this may be avoided by waiting a few minutes for the blood to clot.

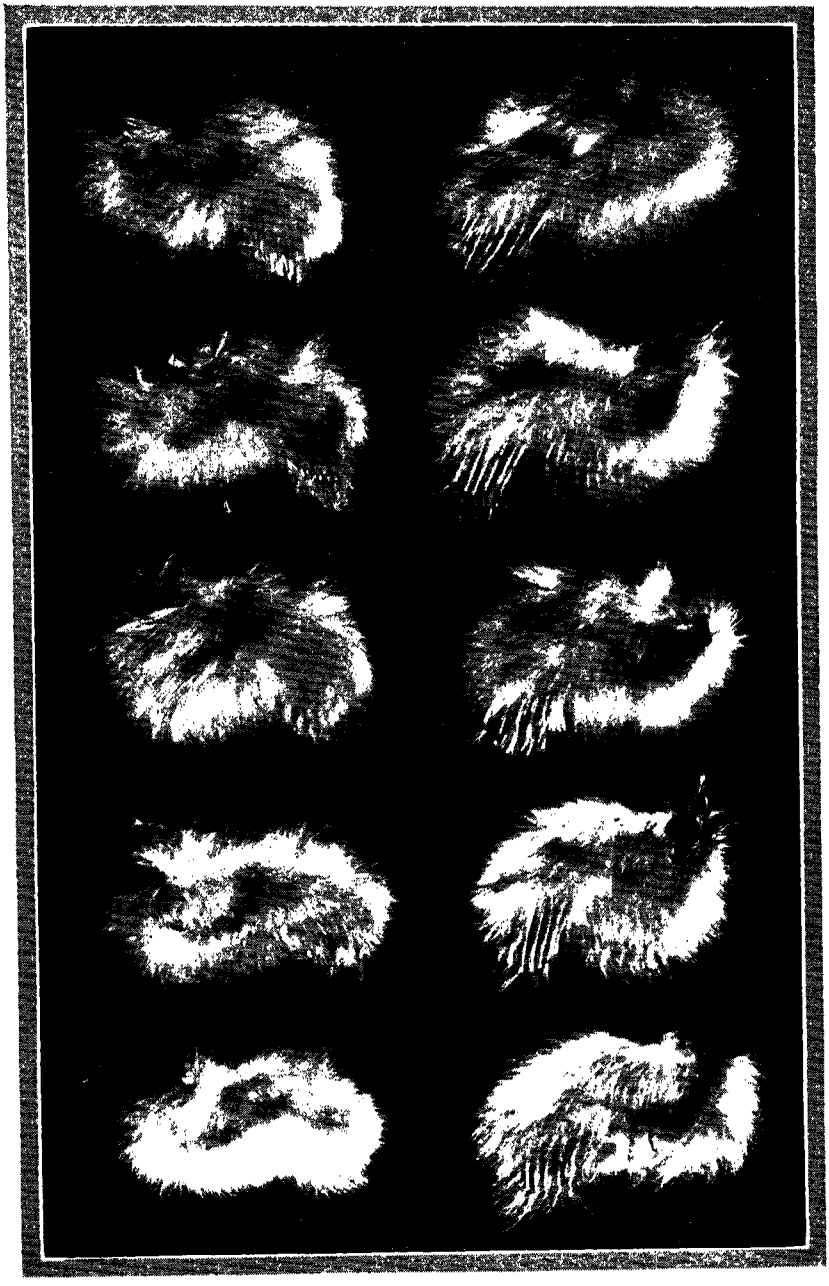

FIG. 15.—A *series of* wings showing the range of flight feather development in day-old male and female chicks from the cross of White Leghorn male by Rhode Island Red females. Note the well-developed flights in the females (right) and the very short flight feathers in the males (left).

FIG. 16.—Growth of wing feathers of newly hatched female (A) and male (B) chicks from the cross of White Leghorn male by Rhode Island Red female.

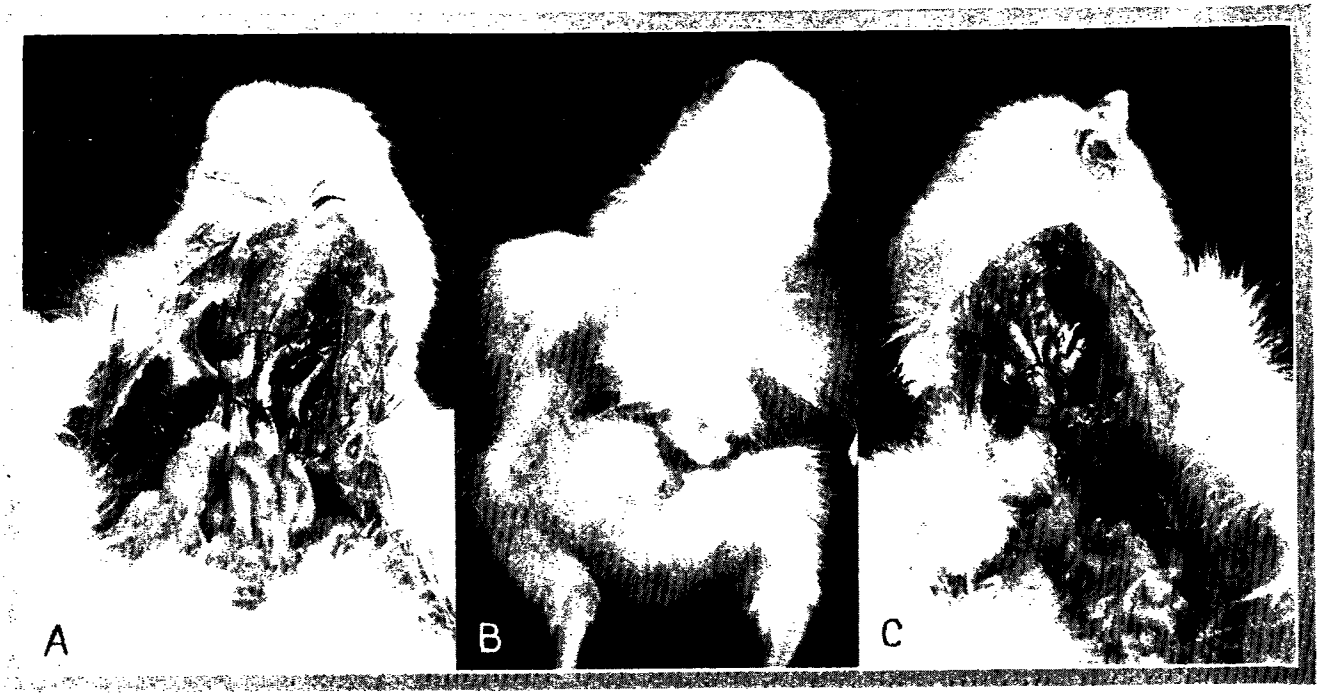

FIG. 17.—The sex glands of day-old chicks. An incision was made across the back and through the ribs on each side as shown in (B). The portion of the back included in the cut has been lifted to show the sex organs (A and C) attached to this region. (A) A male. The paired testes have been encircled in black. (C) A female, with a single sex organ, the ovary, on the left side, also encircled. The ovary is more flattened and differs in shape from the testes.

Accuracy of the New Method

For checking the accuracy of identification of the sexes the writer's observations have been made upon crosses of the White Leghorn male by Rhode Island Red females and Barred Plymouth Rock females. In the first attempt 130 chicks from the cross of White Leghorn male by Rhode Island Red females were classified for sex and immediately killed to check the accuracy of classification. It was found that an error of 8 per cent was made or, in other words, 92 out of 100 chicks had been correctly classified. The eggs had been placed in the incubator about 9 a. m. and the chicks were examined at about 2 p. m. on the same day of the week three weeks later. It is the writer's observation that when the White Leghorn is crossed to a dual-purpose breed, the hybrids hatch just a little earlier than do pure White Leghorn chicks, which themselves hatch earlier than do the dual-purpose breeds.

Since the eggs were pedigree-hatched, it was possible to check back upon the parentage from which errors in classification were made. Records had previously been taken regarding the chick feathering of Rhode Island Red females used in the cross. It was found that a few females had been included that had themselves shown early-feathering as chicks and when their chicks were not considered, all but two of the errors in classification of males were eliminated. Later another group of chicks was reared from a cross of White Leghorn males by a group of Rhode Island Red females from which the early-feathering birds had been removed. One hundred and twenty-eight chicks were classified for sex by means of growth of wing feathers with errors in six cases, making an accuracy of over 95 per cent. Most of the errors were in classifying females as males.

A much smaller number of chicks, 72 in all, from the cross of White Leghorn male by Barred Plymouth Rock females, were classified for sex with an error of 5 per cent.

It is seen that one cannot acquire absolute accuracy by this method, but that a very high degree may be attained. The procedure in separating the sexes has been to place rapidly into two groups the unquestionable chicks and a large per cent of them will be in this class. These two groups will be those with well-developed flight feathers (females) and those showing practically no growth of these feathers (males). The few questionable ones may be placed in a third group for more careful examination after going over the whole hatch. It is in this small group of questionable chicks that

a few autopsies will improve the accuracy of classification for a beginner. The questionable group will usually be found to be mostly of one sex, depending upon when the examination is made. If it is made as soon as most of the chicks are fluffed out, they will be mostly females that have just hatched, or if examination has been delayed a few hours, they will be mostly males that were among the earlier hatching chicks and have begun to show growth of flight feathers.

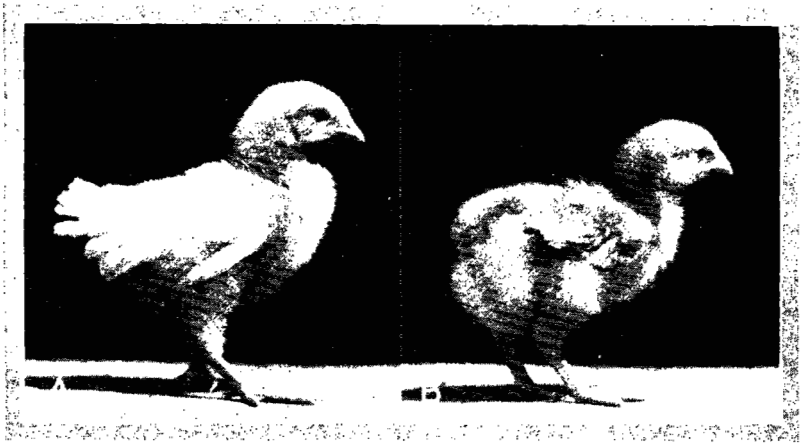

FIG. 18.—An early-feathering White Leghorn (A) and a late-feathering Rhode Island Red (B) at 14 days of age. The accuracy of sex identification in some flocks may be increased by removing from the flock any chicks which between 10 and 14 days show indication of tail feathers. In pure late-feathering flocks, no chicks show tail feathers until after three weeks of age.

The accuracy of this method is probably a little less than where color is used for identification, but other advantages justify the acceptance of the error.

One of the greatest sources of error will be through the use of flocks of females that are not pure for late feathering. It is seen that any females which were as chicks early-feathering will make it impossible to classify correctly their male offspring, since the sons will be early-feathering (have long flight feathers at hatching) instead of late. Fortunately it is a relatively simple matter to eliminate this source of error. If the flock from which the females for mating to the White Leghorn are to be obtained is examined when it is between 10 and 20 days of age, the early-feathering chicks may be detected. Any chick which at this time shows tail

feathers should be removed from the flock or marked so that it will not be used as a breeder. The late-feathering chicks do not show tail feathers before three weeks of age. (Fig. 18.) By this procedure the female flock may be made pure for late feathering and much of the error in classification thus eliminated.

Production of a Late-Feathering White Leghorn

In some sections of the United States the chalk-white egg is at a premium and in such regions the tinted egg of the hybrid would not be acceptable. For the use of down color in sex identification, only brown-egg breeds are available. The method utilizing growth of flight feather uses the White Leghorn male, but all of the late-feathering breeds produce brown eggs.

A white-egg late-feathering breed is not available, but might be easily produced. This could be accomplished by crossing the White Leghorn breed to any late-feathering breed. The hybrid male should then be back-crossed to White Leghorn females and this should be repeated for several generations, each time selecting a late-feathering male. By this method a late-feathering breed could be built up which would have all of the characteristics of White Leghorns, including the white egg. When the new strain had reached a condition closely approaching the standard White Leghorn, the late-feathering male could be mated to late-feathering females from the same generation, and from their offspring could be established a pure-breeding late-feathering White Leghorn. To accomplish this, several males from the last-mentioned mating would need to be tested for purity for late-feathering. This could be done by mating them individually to White Leghorn females. Any male which from among twenty offspring produces no early-feathering chicks may be safely used as a pure-breeding, late-feathering bird. Half of the males from the above-mentioned mating should be pure. Since rate of feathering is a sex-linked character it is not necessary to test the females, because any late-feathering female will breed true. The mating of a tested male to a late-feathering female should give a late-feathering breed which would have practically all of the characteristics of White Leghorns. Any White Leghorn male mated to females of this new strain would produce White Leghorn chicks the sex of which might be identified at hatching. The female chicks would have long flight feathers at hatching and the males would have very short ones.

Advantages of the New Method

The method of identification of sex at hatching from development, of flight feathers has a number of advantages over the method utilizing down color. First it permits the use of the White Leghorn breed which has production qualities that should add materially to the value of the hybrids. The availability of males from this breed is also an important factor, since well-bred birds should be obtainable in any community.

One of the difficulties encountered by hatcherymen attempting to produce crossbreds on a large scale has been to have available enough flocks of females needed for the crosses. The cross utilizing the barring factor could be made only on flocks of Barred Plymouth Rock females. For the gold-silver cross the only widely distributed silver breed is the White Wyandotte. The rate-of-feathering method greatly increases the female flocks available to the hatcheryman, since females from practically any breed other than the Mediterraneans may be used.

The wide popularity of the Barred Plymouth Rock breed has made the barred-nonbarred cross the most available one in America. However, the black color of the hybrid females has been a serious drawback. The use of the White Leghorn male results in crossbreds of both sexes that are predominantly white. This not only avoids the market discrimination against the blacks but supplies a color which is at a premium in some sections. Hybrids are not objectionable in appearance when they are uniform in color. The White Leghorn male when crossed with most breeds, except Rhode Island Reds (fig. 19), produces uniformly white birds with an occasional flecking of black or slight smokiness. (Fig. 20.)

FIG. 19.—First-generation hybrids from the cross of White Leghorn male by Rhode Island Red female. The crossbreds from this mating frequently show some red on the surface of the plumage.

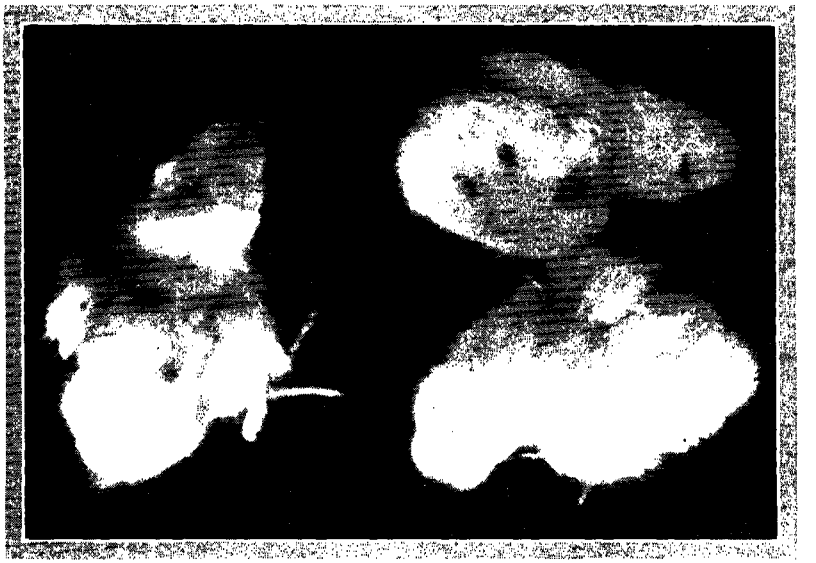

FIG. 20.—Hybrid chicks from the cross of Jersey Black Giant male by White Leghorn females. The chicks from any cross of a black breed by the White Leghorn are white except for an occasional black spot which persists in the adult plumage.

GENERAL DISCUSSION

From the few crosses discussed in this publication it is evident that hybridization in poultry does bring about a stimulation in the general vigor of this species. There is need for more extensive investigations to determine how generally this law holds. There are doubtless other crosses not here studied from which greater stimulation may be obtained, and others in which very little will be manifest. This, at least, has been the experience of plant breeders.

It would seem that the results justify the statement that in the program of the poultryman who is interested primarily in market

FIG. 21.—A group of birds resulting from a mating of White Leghorn-Jersey Black Giant hybrids. Note the variation in color and type and compare with figure 3. Hybrids cannot be used as breeders, but the stock must be replenished by repeating the original cross.

poultry and eggs, crossbreeding has a place. Where the poultryman is interested in a productive animal, it appears that the end may be more economically reached by the use of crossbreds than to attempt to obtain and maintain the most productive strains of pure breds. Since the crossbreeder is dependent upon the pure breeder for renewal of his stock, the practice of crossbreeding should not obliterate the accomplishments of the pure breeder.

There is an element of danger in the possibility that some poultrymen may not heed the warning against the use of crossbreds as breeders. However, one experience should impress this upon the mind of the violator of this law and renew his respect for pure breeds. (Fig. 21.) The hybrid is not in the class with mongrels but

has in most, cases all the qualities that have given the pure bred its high place in the estimation of the live-stock breeder. The chief among these qualities are uniformity and superior productivity, and these are not found in the mongrel. The mongrel is the result of promiscuous breeding while the hybrid is the result of as definite a system of breeding as is the pure bred.

In addition to the economies of production of the hybrid is the possibility of identification of sex at hatching. With the specialization of the industry this is an important factor and allows the hatcheryman to supply his customers with chicks of the sex needed. In the past, identification of sex has been made by down color, either the gold and silver or barred and nonbarred down patterns being used. The new method suggested in this bulletin probably cannot be used with so high degree of accuracy as is down color, but it is sufficiently accurate to meet practical needs. The new method, utilizing the growth of wing feathers, has the advantages of placing at the disposal of the crossbreeder the universally popular White Leghorn; produces a predominantly white hybrid; and greatly extends the list of breeds that may be used in crosses for sex identification at hatching.

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