

THE INHERITANCE OF RHODE ISLAND RED CHICK DOWN-COLOR VARIATIONS AND THEIR RELATION TO COLOR VARIATIONS IN ADULT PLUMAGE¹

By D. C. WARREN

Kansas Agricultural Experiment Station

INTRODUCTION

Any inheritance studies involving variations in the down of chicks have a special theoretical interest because they fall within the category of larval characteristics. Relatively few distinctly larval characters have been made the subject of genetic studies, yet the bearing of these characters upon the problem of the gene in its relation to development is a fundamental one. Color patterns of chick down may be considered as in the nature of larval characteristics for the reason that in many cases the pattern appears to bear little relation to that of the adult. It is true that each adult plumage pattern has a definite corresponding down pattern, but frequently the two patterns have little in common. Both adult and chick down patterns vary to a certain degree, but very little attention has been given to how variations of one affect the expression of the other.

In addition to its theoretical bearing this study has certain practical aspects since any information of predicative value to be obtained from the chicks regarding the color qualities of adults is of considerable value. Rhode Island Red chicks vary widely in the shade of the red color. The lightest individuals are cream colored with only a tinge of red while the darkest are a chocolate brown.

MATERIALS AND METHODS

The stock used in this study was the Single Comb Rhode Island Red flock of the Kansas Agricultural Experiment Station. The strain had been bred for several years as a production flock, and an effort has been made to maintain standard qualities. The average color of the flock is a good dark red, probably above the average quality of most production-bred flocks. As in most flocks of this breed, there is considerable individual variation in the shade of the red color.

In order to keep the classification of chick down color as uniform as possible throughout the study, a standard series of skins was prepared. The skins were arranged in a Riker specimen mount and given grade numbers ranging from 1 to 5. These grades of down color are shown in Plate 1. As soon as chicks were removed from the incubator they were wing-banded and graded according to the standard series. Lighting conditions were kept as uniform as possible while grading was being done.

For recording variations in adult color a detailed description was made at 6 months of age. Wherever possible, standards similar to

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the one used for down color were made up. For recording the shade of red of surface and under color of plumage a Riker mount standard was used. This was made by taking sections of plumage from individuals showing the existing range of color. The record was made by entering the number of the standard grade which most nearly matched the color of the individual. The eye color recorded was that of the iris. The variations noted were in the shade of red which was determined by comparison with a prepared color standard. The standard series used for adult surface and under color and for eye color are shown in Plate 2. Variations in the amount of black pigment in the primary and secondary wing feathers were

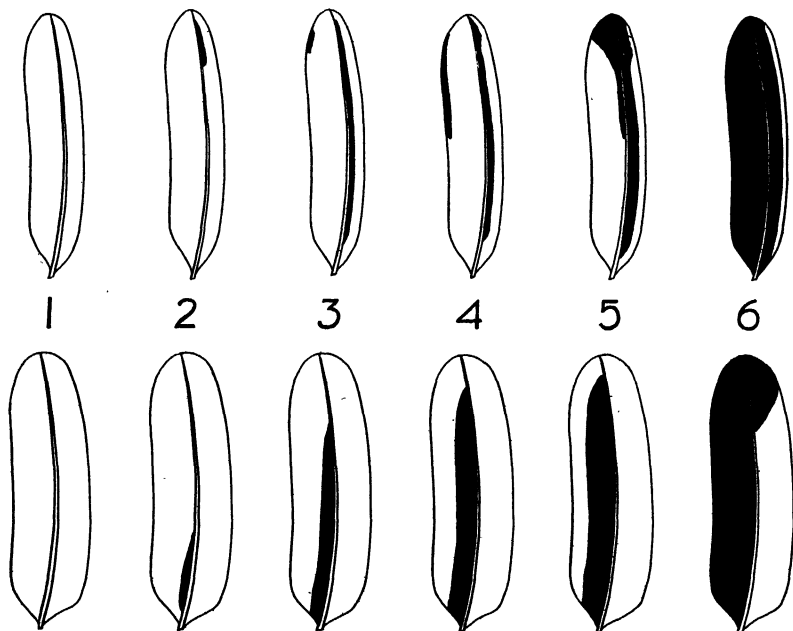


FIGURE 1.—Grade-number standards for variations in the amount of black pigment in the primary (upper series) and secondary (lower series) wing feathers of adult Rhode Island Red chickens

recorded by grade number given in a standard (fig. 1) showing the range of variations. The flight feathers used for recording the grade of black were the second full-length primary and the second secondary. In the description of the surface color the back, hackle, wing bow, and breast were graded separately. The occurrence of black pigment in any section of the surface was also recorded. In addition to recording the shade of under color, note was also made of the presence of smut² or of white in this portion of the plumage.

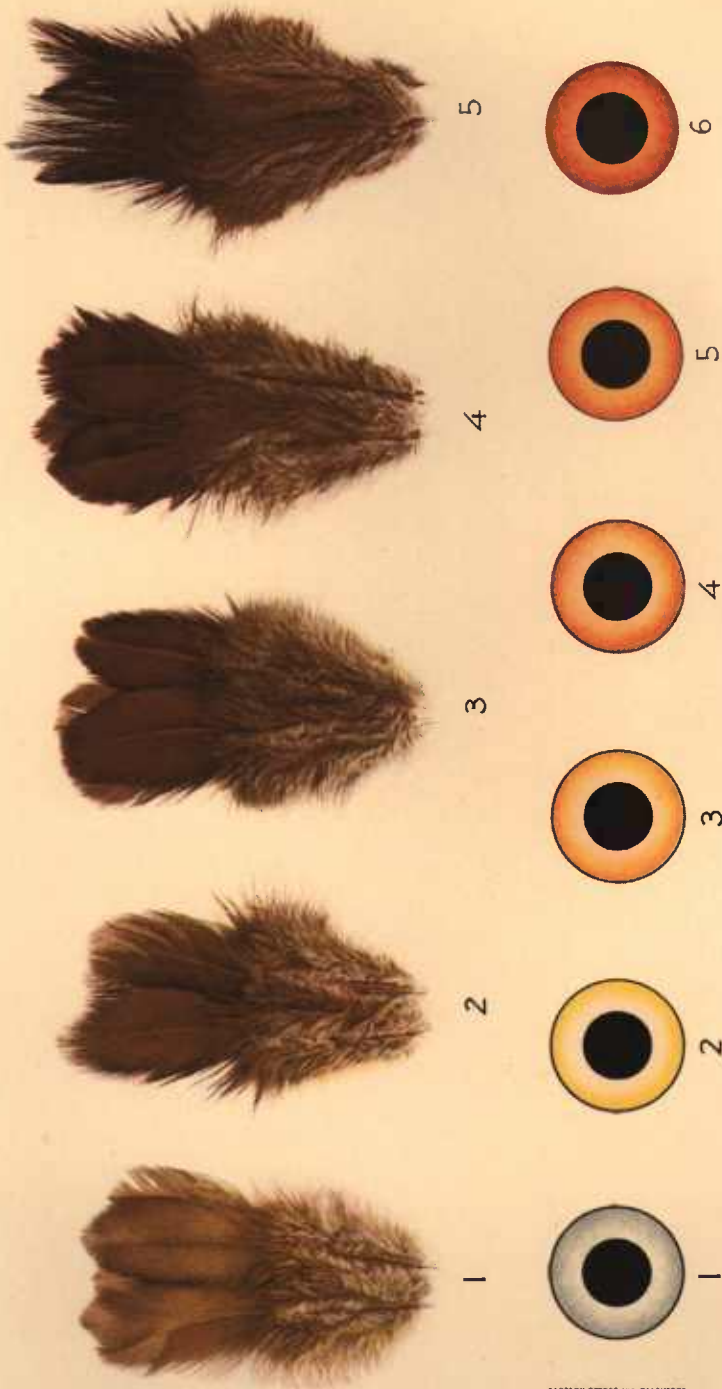
Because of the large number of birds involved it was impractical to preserve entire skins, but a fairly satisfactory substitute was devised. This was a feather card upon which sample feathers from seven representative sections of the plumage were mounted. The

² In the use of the term "smut" the writer has accepted the terminology of the poultry fancier. However, since this word has a different connotation in ordinary usage, the word "soot" would appear to describe much better the presence of black pigment in the under surface of the plumage.



EASTERN OFFSET INC. BALTIMORE

Chicks 1 to 5 show the standard series used for grading down color. Chick A shows striping in an extreme degree



EASTERN OFFSET INC. BALTIMORE

Standard color series used to grade adult surface and under color, and adult eye color. The tips of the feathers show the five grades of surface color. Feathers of the first four grades were taken from females but the grade 5 sample is from male plumage, since females seldom show the darkest color. Feathers 1 to 4 also show the four grades of under color

regions represented were the saddle, hackle, wing bow, back, breast, and the primary and secondary wing feathers. For mounting the feathers a 8 by 5 inch card bearing a double row of loosely set wire staples was used. The feathers were slipped beneath the staples, after which the staples were clamped tightly by the use of a long-lipped pair of pliers. This made for each individual a permanent record, and these records were arranged by families in standard filing cases. Figure 2 shows a filled feather card.

The work upon inheritance of down color covers the period from 1924 to 1928, but the data upon relation of down to adult color are only for the breeding seasons of 1927 and 1928. Relationships of down and adult colors were recorded for the entire period, but only

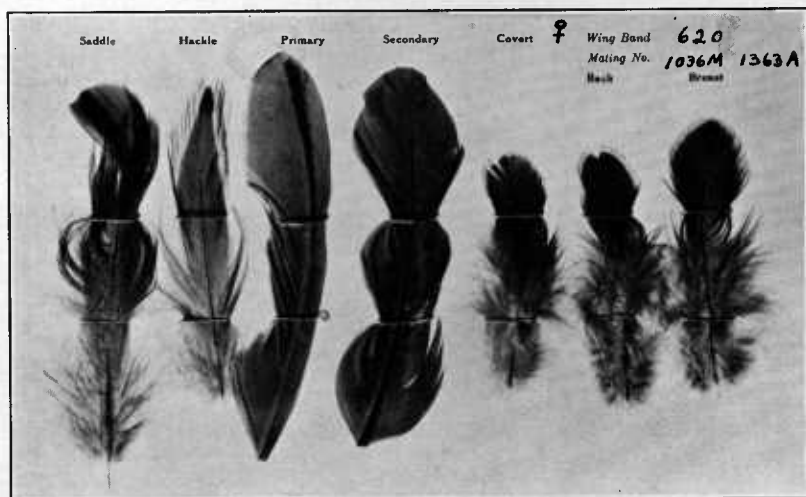


FIGURE 2.—A typical filled feather card containing sample feathers from seven representative sections of the plumage of a Rhode Island Red chicken

during the last two years were the classifications made from standards sufficiently definite to provide data of much value.

INHERITANCE OF DOWN COLOR

During the hatching seasons of 1925 to 1928 selections were carried out for the establishment of a light and dark down strain. Previous to the first season's matings no definite standard had been devised and the birds used for initiating the two strains had merely been described as individuals lighter or darker than the average. During the 1925 hatching season the chick down standard was first used; so that the matings beginning with 1926 were of birds of a known down grade. For the light strain, only birds whose down colors were of grades 1 and 2 were used, most of them being of the lighter grade. In the dark down selections all individuals used were of grades 4 and 5. Table 1 shows the results of the four years' selection. It will be seen that there is no sexual dimorphism with respect to down color, since the males and females in each generation show very similar distributions. Selection was much more effective in the light strain than in the dark one, and during the 1928 season a large

majority of the chicks in the light strain were of grade 1 with a limited number falling in grade 2. The last two years' results for the dark strain show a higher percentage of darker chicks than for the two preceding years, but in all generations there was a considerable number of grade 3 chicks. During the last two years' matings practically no chicks as dark as grade 3 were obtained in the light strain. Thus at the time of crossing of the two strains in 1927 there was practically no overlapping of the distributions of the light and dark strains.

TABLE 1.—Results of selection for light and dark down-color strains—Rhode Island Red chickens

SELECTION FOR LIGHT STRAIN (LIGHT BY LIGHT)

Year	Number of females of grade—					Number of males of grade—				
	1	2	3	4	5	1	2	3	4	5
1925.....	8	10	8	-----	-----	9	13	6	-----	-----
1926.....	7	28	18	-----	-----	8	29	14	-----	-----
1927.....	29	29	3	-----	-----	39	29	3	-----	-----
1928.....	36	8	-----	-----	-----	32	7	-----	-----	-----

SELECTION FOR DARK STRAIN (DARK BY DARK)

1925.....	-----	-----	9	4	-----	-----	-----	9	3	-----
1926.....	-----	1	37	25	2	-----	1	46	17	1
1927.....	-----	-----	29	27	1	-----	1	23	26	2
1928.....	-----	-----	11	7	1	-----	-----	9	9	2

TABLE 2.—Results of crossing of light and dark down-color strains—Rhode Island Red chickens

F₁ GENERATION

No.	Mating	Number of females of grade—					Number of males of grade—				
		1	2	3	4	5	1	2	3	4	5
1	Dark male by light female.....	-----	-----	33	2	-----	-----	3	32	5	-----
2	Light male by dark female.....	-----	9	73	7	-----	1	12	52	8	-----
	Total.....	-----	9	106	9	-----	1	15	84	13	-----

F₂ GENERATION

3	Male from mating 1 by female from mating 1.....	2	12	24	10	-----	7	3	15	5	-----
4	Male from mating 1 by female from mating 2.....	6	34	59	13	3	3	28	67	10	2
	Total.....	8	46	83	23	3	10	31	82	15	2
	Grand total, both sexes.....	18	77	165	38	5	-----	-----	-----	-----	-----

Reciprocal matings between the dark and light strains were made in 1927. The results of these crosses are shown in Table 2. Most of the F₁ offspring fall in grade 3, being intermediate between the two strains, but a few grade 2 and grade 4 chicks were also obtained.

The fact that the female chicks from the cross of light male by dark female are slightly lighter than those from its reciprocal might be taken to indicate that sex-linked factors are involved. However, the male offspring of this cross are also lighter, and this would not be the expected result from sex-linked inheritance. It would therefore appear that the difference between the reciprocals is more likely to be due to individual differences in the birds used as parents.

Table 2 also shows the results obtained for the F_2 generation produced in 1928. There are two series of F_2 's, one resulting from the mating of F_1 females of the cross light male \times dark females, and the other of females from the reciprocal cross. Both kinds of F_1 females were mated to the same F_1 male which was from the cross of a dark male by a light female. The F_1 individuals used to produce the F_2 generation were all of grade 3, this being the predominating color of that generation. The results for the F_2 generation show a distribution including the entire scale of grades. There was no significant difference between the down-color distribution of the offspring of the two lots of F_1 females. In Figure 3 are shown graphically the totals from Table 2 and the 1927 results from Table 1. The intermediate position of the F_1 graph would suggest a multiple-factor situation. However, the rapidity with which the dark and light strains were established by selection would indicate that the number of determining factors is not large. If we accept the variability occurring in the F_1 generation as an expression of the action of a single pair of genes and construct an estimated F_2 graph, we obtain one which approximates the F_2 results. The estimated graph was constructed by dividing the 303 F_2 individuals into three lots—one-fourth homozygous lights, one-fourth homozygous darks, and one-half heterozygotes. The estimated 76 lights (one-fourth of 303) were distributed over the range of color grades, shown by the 1927 light mating. In a like manner the same number of darks was distributed over the grades according to the range of the dark mating for the same year. The 151 heterozygous chicks were given a distribution modeled after the F_1 results of 1927. The estimated distributions (increasing in darkness of red from left to right) were as follows:

Grades.....	1	2	3	4	5
Lights.....	43	31	2	0	0
Darks.....	0	0	37	37	2
Heterozygotes.....	0	15	121	15	0

If the distributions for these classes are summed up, we find that the total estimated distribution corresponds relatively closely with the actual results:

Grades.....	1	2	3	4	5
Observed.....	18	77	165	38	5
Estimated.....	43	46	160	52	2

Although the estimated appears to fit fairly closely the observed distribution, the application of the χ^2 test³ for goodness of fit indicates that the difference here is significant and that a single pair of genetic factors does not fully account for the results. The χ^2 value was found to be 43.86, and the value of P , 0.000000. If the above results are examined it will be seen that the greatest differences in distribution come in the first two classes. If grades 1 and 2, and 3

³ YULE, G. N. AN INTRODUCTION TO THE THEORY OF STATISTICS. 5th ed. London.

and 4 are totaled in the estimated and obtained distributions, the fit is much better and shifts between these grades could easily have been due to errors in judgment. The χ^2 test is probably as reliable a test as can be applied to data of this kind, but in cases of extreme shifts between closely associated classes its degree of reliability can probably be questioned. In view of the above results, any attempt to estimate definitely the number of pairs of genetic factors involved in determining down color is probably unjustifiable. However, it appears to the writer that a single pair of autosomal factors will account for the major variations found in Rhode Island Red chick down color. Other minor factors probably operate, but they do not prevent the one pair of factors from accounting fairly satisfactorily

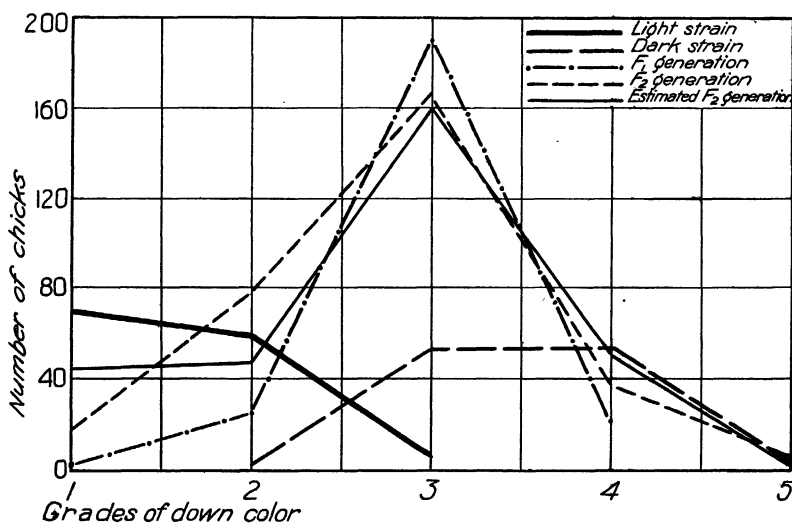


FIGURE 3.—Curves showing graphically the results of crossing light and dark color strains in Rhode Island Red chickens, drawn from figures given in Tables 1 and 2

for the results obtained. The F_1 generation shows neither condition to be dominant, since the distribution in this generation is intermediate between that of the two strains crossed.

COLOR STANDARD AND COLOR VARIATIONS

The ideal color for the Rhode Island Red breed as described in the American Standard of Perfection ⁴ (1923 edition) is as follows:

The plumage * * * should be rich red, except where black is specified, though the neck, wing bows, back, and saddle of the male should be a very lustrous, rich, brilliant red in order to comply with the Standard requirements of these sections. The less contrast between hackle, wing bows, back, breast, and body, the better, as an even shade of color throughout and an harmonious blending in all sections is desired. The shade of color should neither be so light a red as to suggest orange, nor so dark as to have a brownish or violet hue. An even, rich, brilliant red is preferred.

⁴ AMERICAN POULTRY ASSOCIATION. THE AMERICAN STANDARD OF PERFECTION ILLUSTRATED. A COMPLETE DESCRIPTION OF ALL RECOGNIZED VARIETIES OF FOWLS AS REVISED BY THE AMERICAN POULTRY ASSOCIATION AT ITS FORTY-SEVENTH ANNUAL MEETING AT FNOXVILLE, TENN., NINETEEN HUNDRED TWENTY-TWO. 1923 ed. 427 p., illus. n. p. 1923.

The primary wing feathers should be red like the rest of the plumage except the lower web which should be black with a red edging; the secondary wing feathers should have the black only in the upper web.

One of the common defects in the Rhode Island Red breed is that the general color is too light or too dark and the latter condition is usually accompanied by some black pigment on the surface. The breast is frequently much lighter than the rest of the plumage, this being a more common trait of females. The under color (the fluff portion of the feather which is hidden by overlapping) should match as closely as possible the general surface color, but this also varies considerably in shade, usually being lighter than the surface. The occurrence of black pigment in the under color, usually termed "smut," is a common defect. The appearance of white in the under color is also frequent, especially in males. The amount of black in wing feathers is frequently reduced or even may be entirely lacking.

The color of the eye varies from a dull gray to a reddish bay, the latter being the desired color. It was with these more common defects which were readily classifiable that the association of variations in down color was measured.

RELATION OF DOWN COLOR TO ADULT COLOR VARIATIONS

DOWN COLOR AND ADULT SURFACE COLOR

By surface color is meant the color of the back region, since the hackle and breast sections were classified separately. This is the section from which one would ordinarily get an impression of a bird's general color. The grades of surface color given in Tables 3 and 4 are those determined by comparison with the plumage standard already described. In this summary, as in all succeeding tables, the results of not only the down-color matings are given, but those of all Rhode Island Red matings for the period covered.

Since the males averaged somewhat darker than females with respect to surface color, it was necessary to tabulate the sexes separately. The results here confirm the statement made earlier that no sexual dimorphism exists with respect to down color, as the total distributions of the two sexes are very similar. In Tables 3 and 4 the darkness of the red in both down and adult plumage increases directly with the value of the grades. The coefficient of correlation⁵ of down and surface color of males (Table 3), was found to be 0.179 ± 0.020 . A value of so small a magnitude has, of course, no significance. In Table 4 are the data for the relationship in females of down and surface color. The coefficient of correlation was found to be 0.229 ± 0.016 , and, although higher than that of males, it is too small to be considered significant. Tables 3 and 4 show that the chicks of down-color grades 1 and 2 (both of which are very light) fall in all grades of plumage color. In other words, chicks of the lightest grades of down color may as adults be some of the darkest as well as some of the lightest-colored birds of the flock. However, the two darkest grades of down color (grades 4 and 5) produced adults all but two of which were grade 3 or darker. So, although light chicks may produce very dark adults, dark chicks seldom produce light adults. The intermediate down grade 3, like the lighter grades, produced adults having almost the full range of plumage shades.

⁵ BABCOCK, E. B., and CLAUSEN, R. E. GENETICS IN RELATION TO AGRICULTURE. 2d ed. New York.

TABLE 3.—Correlation between chick down color and adult plumage color (males only)

Grades of adult color	Number of chicks with down color of grade—					Total
	1	2	3	4	5	
1.....		1				1
2.....	2	2	1			5
3.....	9	23	56	6	1	95
4.....	22	56	233	43	1	355
5.....	3	12	34	11		60
Total.....	36	94	324	60	2	

Coefficient of correlation 0.179 ± 0.020 .

TABLE 4.—Correlation between chick down color and adult plumage color (females only)

Grades of adult color	Number of chicks with down color of grade—					Total
	1	2	3	4	5	
1.....	1	3	4			8
2.....	10	25	60	2		97
3.....	9	59	214	35		317
4.....	5	25	117	27	1	175
5.....		1	1			2
Total.....	25	113	396	64	1	

Coefficient of correlation 0.229 ± 0.016 .

DOWN COLOR AND BREAST COLOR

The plumage of the breast frequently is much lighter in color than the rest of the body. This is particularly true of females, and for that reason only females were considered in calculating the relation of down color to adult breast color. From Table 5 it is seen that no significant correlation exists, the coefficient being 0.238 ± 0.015 . The value of the coefficient is very similar to that obtained for females when the surface color other than that of the breast was considered.

TABLE 5.—Correlation between chick down color and adult breast color (females only)

Grades of adult breast color	Number of chicks with down color of grade—					Total
	1	2	3	4	5	
1.....	9	18	29			56
2.....	4	37	132	14		187
3.....	8	42	150	27	1	228
4.....	4	16	85	23	1	129
5.....		1	1			2
Total.....	25	114	397	64	2	

Coefficient of correlation 0.238 ± 0.015 .

DOWN COLOR AND EXCESS BLACK IN ADULT-PLUMAGE SURFACE COLOR

Particularly in strains of Rhode Island Reds which have been selected for a very dark shade of red there is a tendency to show varying amounts of black pigment on the surface. The appearance of black pigment anywhere except in the hackle of females and in wings and tail of either sex is undesirable. The males show black to a much lesser degree and for that reason only the data for females have been included in Table 6, where the relation of down-color variations to black in the plumage surface of adults is considered. This table shows the down-color distribution of those individuals showing black on the plumage surface in comparison with those free from it. The application of the χ^2 test indicates that the difference between these two distributions is not significant, since the value of P is slightly less than 0.029. In the application of the χ^2 test the method developed by Pearson⁶ for comparing two independent distributions of frequency from the same population but differing in N value, was used. This method was also used for calculating the χ^2 value from Tables 9 and 10. Since there is no significant difference between the down-color distributions for birds showing and lacking excess black on the surface, it may be said that the grade of down color does not affect the occurrence of black in this region.

TABLE 6.—*Relation of down color to the occurrence of excess black in adult surface color (females only)*

Item	Number of chicks with down color of grade—				
	1	2	3	4	5
Adults showing excess black.....	4	30	103	30	1
Adults lacking excess black.....	24	84	306	48	6
$\chi^2=8.77$ $P=0.029$					

DOWN COLOR AND UNDER COLOR

The term "under color" as used by the poultry fancier refers to the color of the fluff sections of the feather. This is the basal portion of the feather which is usually hidden by overlapping. The under color was classified into four grades and its relation to chick down color is shown in Tables 7 and 8. The fluff sections of the feathers shown in Plate 2 present the four grades of under color, 1 to 4. Table 7 gives the data for males and Table 8 that for females. For each sex there is a significant positive correlation. For males the coefficient of correlation was found to be 0.478 ± 0.008 and for females 0.517 ± 0.006 . In each case these values may be considered significant, indicating that the lighter colored chicks have a tendency to develop into adults with under color which is lighter than the average. These results are clearly shown in Tables 7 and 8, for the chicks with down-color grades 1 and 2 mostly fell in adult grades 1 and 2 while the two darkest down-color grades seldom had adult plumage as light as grade 2.

⁶ PEARSON, K. ON THE PROBABILITY THAT TWO INDEPENDENT DISTRIBUTIONS OF FREQUENCY ARE REALLY SAMPLES FROM THE SAME POPULATION. *Biometrika* 8: 250-254. 1911.

This association could not have been the result of any bias of judgment on the part of the investigator, for he recorded the adult plumage grades without knowing what the down-color grade had been.

TABLE 7.—Correlation between chick down color and adult under color (males only)

Grades of adult under color	Number of chicks with down color of grade—					Total
	1	2	3	4	5	
1.....	5	4				9
2.....	24	49	90	4		167
3.....	6	37	214	53	2	312
4.....		6	20	4		30
Total.....	35	96	324	61	2	

Coefficient of correlation 0.478 ± 0.008 .

TABLE 8.—Correlation between chick down color and adult under color (females only)

Grades of adult under color	Number of chicks with down color of grade—					Total
	1	2	3	4	5	
1.....	4	9	1			14
2.....	18	72	147	8		245
3.....	3	30	218	42	1	294
4.....		3	30	15	1	49
Total.....	25	114	396	65	2	

Coefficient of correlation 0.517 ± 0.006 .

DOWN COLOR AND SMUT IN UNDER COLOR

The occurrence of smut in under color is a common defect in Rhode Island Reds. In Table 9 is shown the relation of smut to down color. For determining whether the grade of down color in any way affects the occurrence of smut, the birds were divided into two classes, those showing smut and those lacking smut. If down color influences the occurrence of smut, the two classes should show a difference in distribution for down color. Table 9 shows that the individuals exhibiting smut had lighter average down color than those lacking it. This was true for both sexes and the difference between the down-color distribution for the two lots was found to be significant from the application of the χ^2 test. Although many light chicks were free from smut and there were several of the darker grades which showed it, a difference in average down color of the two lots is evident.

TABLE 9.—Relation of down color to the occurrence of smut in adult under color

Item	Number of chicks showing down color of grade indicated—																			
	Females					Males														
	1	2	3	4	5	1	2	3	4	5										
Adults showing smut.....	18	39	64	7	1	15	15	24	8											
Adults lacking smut.....	14	79	351	69	2	22	74	305	51	2										
	$\chi^2=50.08$					$P=0.000000$					$\chi^2=37.73$					$P=0.000000$				

DOWN COLOR AND WHITE IN UNDER COLOR

A common defect in Rhode Island Reds is the occurrence of white sections in the under color. This defect is found much more frequently in males than in females. The saddle is the section of the plumage where white more usually appears. The extent of white varies from a few feathers to large sections of the under color. Since the stock used for these studies showed white in under color somewhat infrequently in females, data are given for males only. (Table 10.) The comparison made was of individuals lacking and those having white in under color. The results show that the birds having white in under color had, as chicks, down which averaged considerably lighter than that of the birds that were free from this defect. To state the results in another way, the light-down chicks are more likely to show white in their under color as adults than the dark-down chicks. Of the 63 chicks having down of the color grades 4 and 5, only 9 showed white. Of the 127 chicks having down of color grades 1 and 2, 54 showed white and 73 showed none. The application of the χ^2 test for goodness of fit indicates that the difference obtained here is significant.

TABLE 10.—*Relation of down color to the occurrence of white in under color (males only)*

Item	Number of chicks showing down color of grade—				
	1	2	3	4	5
Adults showing white.....	18	36	56	9	-----
Adults lacking white.....	17	56	269	52	2
$\chi^2=47.7 \quad P=0.000000$					

DOWN COLOR AND BLACK IN WING

The amount of black in the primary and secondary wing feathers varies widely. In some cases black is entirely absent and in others it extends over practically the whole feather. These studies have shown that there is a very close correlation between the amount of black in the primary and in the secondary feathers. As has already been stated, the classification of grade of black in wing was determined by comparison with an arbitrarily graded standard, which is shown in Figure 1. To determine whether variations in shade of down color showed any relation to the amount of black in the wing, Tables 11 and 12 were made. Since the males show considerably more black in the wing than females, the records for the two sexes are presented separately. The data in these tables are for the primary wing feathers. The results on secondaries are not given since they are very similar. In neither case is the correlation significant, although in Table 12 there appears to be a slight tendency among the males for those in the darker wing grades to have darker down. The coefficient of correlation for males was 0.162 ± 0.028 and for females 0.133 ± 0.020 .

TABLE 11.—*Correlation between chick down color and amount of black in adult wing feathers (females only)*

Grades of black in adult wing	Number of chicks with down color of grade—					Total
	1	2	3	4	5	
1.....		18	34	8		69
2.....	25	52	210	29	1	310
3.....	4	37	125	21	2	184
4.....	2	5	31	12		52
5.....		4	13	7		20
6.....		1	1			7
Total.....	31	117	414	77	3	

Coefficient of correlation 0.133 ± 0.020 .TABLE 12.—*Correlation between chick down color and amount of black in adult wing feathers (males only)*

Grades of black in adult wing	Number of chicks with down color of grade—					Total
	1	2	3	4	5	
1.....	1	1	13	3		18
2.....	19	37	92	11	2	161
3.....	9	23	79	7		118
4.....	4	15	79	24		122
5.....	2	18	58	14		92
6.....	1		2	1		4
Total.....	36	94	323	60	2	

Coefficient of correlation 0.162 ± 0.028 .

DOWN COLOR AND EYE COLOR

The eye color most sought for by the poultry fancier is a brilliant reddish bay. There are found, however, varying shades of red in the eye of Rhode Island Reds. In some cases the red color may be entirely lacking, leaving the eye a light gray. The color referred to is that of the iris. In addition to variations in the amount of red there are differences in distribution of color in the different grades of eye color. The reduction of the red pigment is first seen at the margin of the pupil and the last traces are usually found at the outer edge of the iris. As was true of the plumage, the eye color was not graded until the 6-months age was reached, after which there appears to be very little change. Plate 2 shows from right to left the order of disappearance of red from the eye. Table 13 presents the relationship of down color to eye color. The two sexes showed the following distribution for eye color:

Males.....	5	55	177	183	93	5
Females.....	10	87	244	208	89	4

TABLE 13.—*Correlation between chick down color and adult eye color (both sexes)*

Grades of adult eye color	Number of chicks with down color of grade—					Total
	1	2	3	4	5	
1.....		2	6	7		15
2.....		19	101	21	1	142
3.....	21	80	270	50		421
4.....	28	80	242	35	3	391
5.....	19	28	113	21	1	182
6.....		1	7	1		9
Total.....	68	210	739	138	5	

Coefficient of correlation -0.123 ± 0.015 .

The grades become progressively darker from left to right. The results show no relationship between adult eye color and chick down color, since the coefficient of correlation -0.123 ± 0.015 is statistically insignificant.

DOWN STRIPING AND ADULT PLUMAGE COLOR

Although Rhode Island Red chicks are usually of a more or less uniform red color above, stripes occasionally occur on the back. These are ordinarily brownish in color and vary from definite stripes to small irregular spots. Chick A in Plate 1 shows striping. Striping occurs rather infrequently in the stock studies, so data are available on only a limited number of individuals. The records showed the striped chicks to be preponderantly females (29 females to 5 males). Although the sex ratio is distinctly aberrant, the difference may be a chance one resulting from the small numbers. The records for the 34 chicks that showed striping were studied in relation to the quality of the adult plumage. Much of the data on striping were taken before definite standards were used, and therefore did not lend themselves to uniform tabulation. However, an examination of the descriptions showed that the striped chicks did not differ from the average of other chicks with respect to adult surface color since the range was from light to dark individuals. The distributions for black in wing and eye color were also practically normal. The under color of the striped chicks was, however, found to be of very poor quality. The records for these chicks show that 6 had good red under color, 10 medium, and 18 poor. The quality here is far below the average for the nonstriped chicks. The explanation of this poor quality is found in the data on the occurrence of smut and white in the under surface. Twenty were listed as showing much smut, 8 some smut, 1 slight smut, and 5 no smut. Four showed much white, 10 some white, 5 slight white, and 15 no white. In all, 29 of the 34 showed some smut and 19 showed some white in the under surface. Considering all of the descriptions taken, less than 15 per cent of the females showed smut in the under surface, and the males showed much less. Of the striped female chicks over 85 per cent carried smut. Since so few females showed white in under surface no summaries were made for this sex in the study of white in under color. Although most of the striped chicks were females, over half of them showed some white in under color. One fact which should be taken into consideration is that striping is much more conspicuous in the lighter colored chicks and most of those listed as striped were of the lighter grades. Since it has already been shown that there is a relationship between down color and under color and also between down color and smut, the grade of down may also be a factor here. It can be said, however, that most of the striped chicks had poor quality of under color.

SUMMARY AND CONCLUSIONS

This study was conducted to determine whether Rhode Island Red chick down-color variations were heritable, and, if so, how they were inherited. It was also the purpose of the study to learn whether the variations found in down color bore any relation to adult plumage color variations. Any relationship found would, of course, be of

value in predicting, at hatching, the quality of adult plumage color to be expected. The relationship found between down and adult plumage color are purely physiological and not of the nature of genetic linkages.

It was found that variations in the shade of the down color are inherited and that it was possible to establish strains which bred relatively true for the dark and light red down. A single genetic-factor difference seemed sufficient to explain most variations encountered when the light and dark strains were crossed, neither condition being dominant.

The relationship of down-color variations to the following variations in adult plumage color were determined—general surface color, occurrence of black on the surface, breast color, under color, smut in under color, white in under color, black in the larger wing feathers, and eye color. The only significant correlation was found between the shade of down color and under color, and from this it was learned that a high percentage of the light-colored chicks developed into adults with light under color. In the same way most of the adults with the darker shades of under color showed dark-red down color as chicks. The lightest colored chicks also showed a tendency to develop into adults with under color showing much smut and white. Chicks showing conspicuous striping at hatching are likely to develop into adults with under color of inferior quality, usually carrying considerable smut and white in that section. No agreement was found between the shade of the adult surface color and down color. The chicks having the lightest shades of down might develop into very dark adults. It was found, however, that the dark chicks seldom produced adults of the lighter shades of red.

From a practical point of view, then, the light-colored Rhode Island Red chicks should be eliminated, primarily because of their effect upon the under color of the flock. If only individuals showing the darker shades of down are reared an improvement in under color may be expected. In order to eliminate smut and white from the under color, chicks showing striping should not be reared. If only chicks of the very darkest shades of down color are retained, the lighter colored adults will be avoided.