THE SIGNIFICANCE OF THE SEX-LINKED EARLY-FEATHERING FACTOR IN BARRED PLYMOUTH ROCK CHICKENS.

by

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A THESIS

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Contents.

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INTRODUCTION

Breeds of chickens have been long known to differ in the rate at which the chicks acquire their feathers. Poultrymen have also observed that there is considerable variation in the rate of feathering between individuals within a breed. Serebrovsky (1922) first revealed the hereditary nature of this factor by crossing the early feathering Russian Orloffs with the late feathering Barred Plymouth Rocks. It is now known that the early feathering of chickens, studied by Serebrovsky, is governed by a sex-linked gene which is recessive to late feathering. Although certain breeds of chickens are normally classed as late feathering, a few individuals within these breeds possess the sex-linked early-feathering factor. The unveiling of these facts has opened a new field of research and allows for practical application of the principle involved, without resorting to cross-breeding.

Due to the fact that in poultry the female has only one sex-chromosome and the male two, only the latter can be heterozygous for this sex-linked feathering factor. Therefore the homozygous early feathering males (s s) and the "hemizygous" early feathering females (s-), can be detected in day old chicks by the presence of well defined primary wing feathers. This has led to the development of a new method of sexing chicks, first suggested by Warren (1930).

Some commercial hatcheries are now making use of this principle, particularly in White Leghorn chicks. By mating homozygous early feathering males with late feathering females, the chicks are sexed at hatching time by means of well developed primary wing feathers in the female chicks but not in the males.

Within the past few years pure sex-linked early feathering strains have been established in several hitherto slow feathering breeds of chickens. The Massachusetts State Agricultural College has developed a strain of this type in the Rhode Island Red breed. The Kansas State Agricultural College has reported a similar strain of White Plymouth Rocks. The Ontario Agricultural College is known to have sex-linked early feathering Barred Plymouth Rocks, and in 1942 chicks of this type were offered for sale by an Ontario breeder.

Several workers have produced evidence that there is a high correlation between the sex-linked early-feathering factor and satisfactory feathering at the broiler stage. This offers new possibilities for late feathering breeds in the broiler trade. Hitherto young cockerels of otherwise popular but late feathering breeds, have been subject to severe market discriminations on account of an excess of pin feathers over the body. It is impossible to make an attractive dressed carcass from a bird which reaches the market in a poorly feathered condition. Cockerels sold as broilers command significantly higher prices if they exhibit complete body feathering.

From the standpoint of brooding and rearing, poultrymen in general favour early feathering strains of chickens. A coat of feathers gives protection against chills resulting from flutuations in temperature during the early brooding period. Moreover, such birds are ready for exposure to outdoor range conditions at an earlier age. According to Gericke and Platt (1932), Voit found that the metabolism of the pigeon may actually be doubled after removing feathers, indicating an effort on the part of the body to maintain normal temperature at the expense of food consumed. It is believed by some workers that early feathering offers some protection against cannibalism.

The foregoing statements reveal the importance of feathering in chickens. Geneticists and poultry breeders, the hatcheryman and the producer of market poultry, have all made use of the sex-linked principle involved. Rate of feathering is of special interest to Canadian poultry breeders, since Barred Plymouth Rocks, normally a late-feathering breed, constitute possibly 40% of the pure-bred chickens raised in Canada. With the present tendency of breeders to purify strains of Barred Plymouth Rocks for sex-linked early feathering, it is important to determine, from an economic standpoint, the desirable or undesirable traits with which this factor may be associated. To date relatively little information is available on this point.

The object of the present investigation is as follows:

(1) To establish the relationship between sex-linked early feathering and various other characteristics of economic value in Barred Plymouth Rocks.

(2) To purify an early feathering strain of the breed and yet retain, if possible, the existing desirable traits.

(3) To verify the single recessive type of inheritance of the sex-linked early feathering genes, previously established by other workers.

Excepting quotations, the terms "early feathering" "sex-linked feathering," and "sex-linked factor" as used in this thesis, refer to the sex-linked early-feathering factor, unless otherwise stated.

Review of Literature

The first attempt to explain the difference in rate of feathering between breeds of chickens (or individuals), on the basis of heredity, was made by Rogers (1909). He claimed that, in crosses between White Leghorns and Barred Plymouth Rocks, the chicks feathered at a rate similar to that of the sire irrespective of the direction of the cross.

The first report of a sex-linked gene, affecting the rate of feathering in chickens, was presented by Serebrovsky (1922). He obtained evidence of this nature by crossing Russian Orloffs, an early feathering breed, with late feathering Barred Plymouth Rocks. His findings were later confirmed by Warren (1925 b) who worked with Single Comb White Leghorns and Jersey Black Giants. Warren (1925b) stated that this sex-linked character shows clean cut segregation and is expressed early in life. Warren (1925 b) used the presence of well defined primary wing feathers in day-old chicks, and the appearance of tails at 10 days of age, as the basis for classifying chicks into "slow" and "quick" feathering. He observed that the White Leghorns showed tail feathers within the first week while the Jersey Black Giants did not grow tail feathers before the 16th day. Warren (1925 b) finally concluded that examination, at 12 days of age for presence of tail feathers, gave the most accurate results in classifying chicks for the sex-linked feathering factor, but that this character cannot be recognized in the adult birds.

According to Martin (1932), Saharova in 1926 made an extensive study with chicks of various breeds and classified them into "slow" and "quick" feathering. He included the Plymouth Rocks in the slow feathering group. Danforth (1929), using Barred Plymouth Rocks and Rhode Island Reds, obtained evidence that the sex-linked late-feathering gene, designated as "S" by Serebrovsky (1922), is present in both of these breeds. Working with Rhode Island Reds, Hays (1938) also confirmed the fact that early feathering in that breed is governed by the sex-linked recessive gene "s". Radi and Warren (1938) concluded that sex-linked early feathering stock cannot be obtained from genetically late-feathering birds. They further added that sex-linked early feathering, commonly present in the Mediterranean breeds and occasionally found in individuals of the large breeds, probably offers the practical method of developing such a strain.

Contrary to most previous findings, Lloyd (1939) claimed that "it was not found possible to make an accurate or satisfactory classification of the feather growth of young cockerels at 4 weeks" and further adds that "at 8 weeks, however, feathering was sufficiently advanced to permit of definite classification." He also believed that rapid feathering behaves as a dominant in inheritance. However the same author (1941) stated in a popular poultry magazine that "it was not until the feather growth was studied at 4 weeks, in 1939, and then at 1 day old and 10 to 14 days in 1940, that the true early-feathering stock could be identified with certainty." In the same article he states that "some well known geneticists are bringing in the fast-feathering sex-linked gene from the New Hampshire or other breeds. The best method has not yet been demonstrated."

From the findings of the previous workers there is little doubt that a condition of feathering, such as that present in the early feathering breeds, is sex-linked and recessive to late feathering. Furthermore that, occasionally, sex-linked early feathering individuals are found in practically all the late feathering breeds from which a pure early feathering strain can be developed. It is on the above findings that the present investigation is based. However, since all data presented in the thesis are based on the hereditary nature of the sex-linked early-feathering factor as described by previous workers, it was necessary to check the genetic principle involved for any possible disagreement.

Method and Material.

The plan of the experiment took into account the fact that environmental conditions have been shown to influence the rate of feather development.

Gericke and Platt (1932) showed that feather development over the entire body increased significantly in direct relation to the amount of protein in the ration. Later a group of workers at the Ontario Agricultural College (1938) suggested that both a deficiency and an excess of protein influence feathering. According to Fuller and Wilcke (1942), Branion stated that feathering in general is retarded in corn fed lots although these chicks were superior in growth to the wheat, oat groats, and barley groups. Similar results were obtained by Poley (1938).

Recent work by Hegsted et al (1941), on the role of arginine and glycine in chick nutrition, indicates that a diet deficient in these substances results in very poor feather structure. However this was more pronounced in rapidly feathering White Leghorns than in the slower feathering Barred Plymouth Rock chicks.

Miller and Bearse (1937, 1938), Wilcke (1936), Wilcke and Hammond (1940), Mussehl et al (1940) and Fuller and Wilcke (1942), all demonstrated the beneficial effect of oats, oat hulls, and bran in poultry rations on the growth and quality of feathering. Thompson (1940) concluded that the action of oat hulls and wheat bran in improving the rate of feathering is simply the result of better body growth.

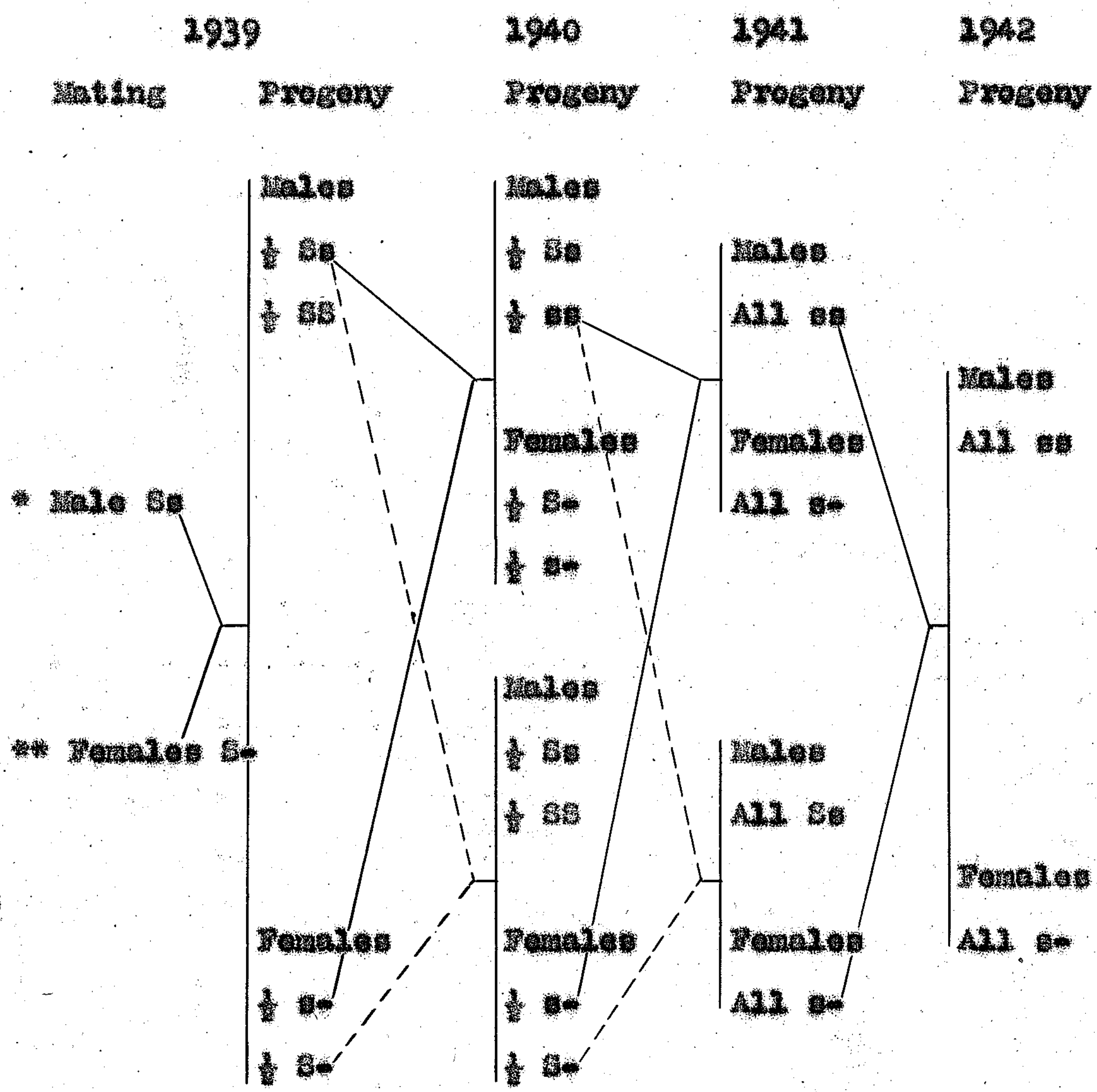
Briggs et al (1942) report on the important role of a little-known vitamin called "folic acid," essential for normal growth, blood building, and feathering of growing chicks. Nowotarski and Bird (1943), in their study of calcium, phosphorus, and Vitamin D requirements of the chick, observed that the "addition of 0.1% choline to the mineralized A. O. A. C. vitamin D deficient diet, with or without added Vitamin D, improved growth, feed efficiency, and feathering."

With regard to brooding conditions, Callenbach et al (1937) showed that brooder temperature and relative humidity did not affect plumage growth and condition as measured by primary wing feather development of Barred Plymouth Rock pullets at 10 to 16 weeks of age, or plumage condition of Barred Plymouth Rock cockerels graded when 8 weeks old. However, according to the above authors, Ackerman et al, and Moore and Gallagher presented conflicting evidence on this subject.

An attempt has been made in the following study to reduce experimental error to a minimum. All rations fed were

Figure 1.

Genealogy of the Early Feathering Strain.



* Ss male obtained from Mr. Fred N. Jerome.

** S- females came from: Brandon, O. A. C., U. of M.

SS are homozygous late feathering males.

Ss " heterozygous " " "

ss " homozygous early " "

S- " pure late feathering females.

s- " " early " "

prepared at the University and kept as uniform as possible from year to year. All the birds were hatched in the same incubator, brooded and reared together in mixed lots of early and late feathering chicks, and likewise housed in mixed lots as adults. Some matings were designed to produce both early and late feathering chicks from the same parents, thus limiting the genetic variation to the rate of feathering factor and its possible effects on other traits.

The sex-linked early-feathering factor was introduced into the University flock in the spring of 1939 by a heterozygous late feathering male (S s), figure 2, obtained from Mr. Fred N. Jerome of Bray Hatcheries Limited, Hamilton, Ontario. According to communications Mr. Jerome observed a few early feathering pure-bred Barred Rock female chicks in the approved flocks in Ontario. He mated these with a late feathering R.O.P. male, and produced heterozygous late feathering males, including the one used at the University of Manitoba.

The plan of breeding followed in the development of the pure sex-linked early feathering strain of Barred Plymouth Rocks, is shown in figure 1. In anticipation of rather close inbreeding to follow, females used in the original mating were obtained from several different breeders.

Explanation of Figures.

Fig. 2. The heterozygous late feathering B.P. Rock male (Ss) obtained from Fred H. Jerome.

Fig. 3. Wings of day-old B.P. Rock chicks.

1. Homozygous late feathering male (SS).
2. Heterozygous " " " (Ss).
3. Homozygous early " " (ss).
4. Late feathering female (S-).
5. Early " " (s-).

Fig. 4. Two week old B.P. Rock females.
left - late feathering; right - early feathering.

Fig. 5. Two week old B.P. Rock males.
left - late feathering; right - early feathering.

Fig. 6. One week old B.P. Rock females.
left - late feathering; right - early feathering.

Fig. 7. One week old B.P. Rock males.
left - late feathering; right - early feathering.

Fig. 8. Left - Two week old New Hampshire chick.
Right - Two week old early feathering B.P. Rock chick.

Fig. 9. Three week old B.P. Rock females.
left - late feathering; right - early feathering.

Fig. 10. Three week old B.P. Rock males.
left - late feathering; right - early feathering.

Fig. 11. 1. Wing of day-old early feathering B.P. Rock chick.
2. Wing of day-old New Hampshire chick.

Fig. 12. Two week old early feathering B.P. Rock chick showing "retarded" factor.

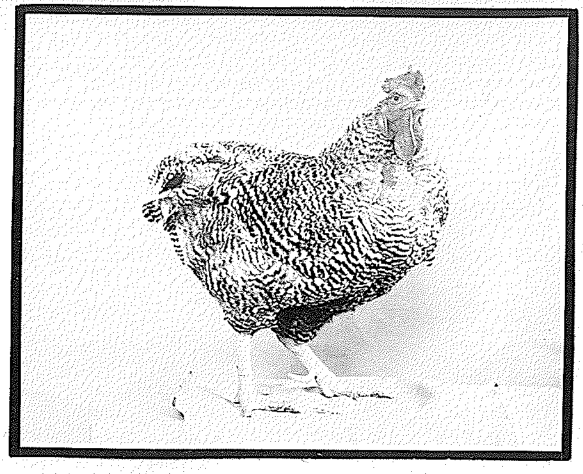
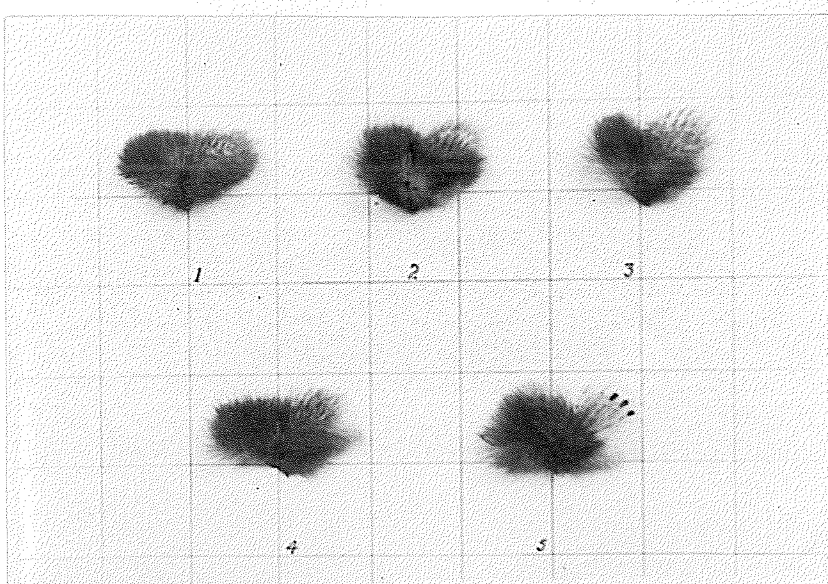


Figure 2.



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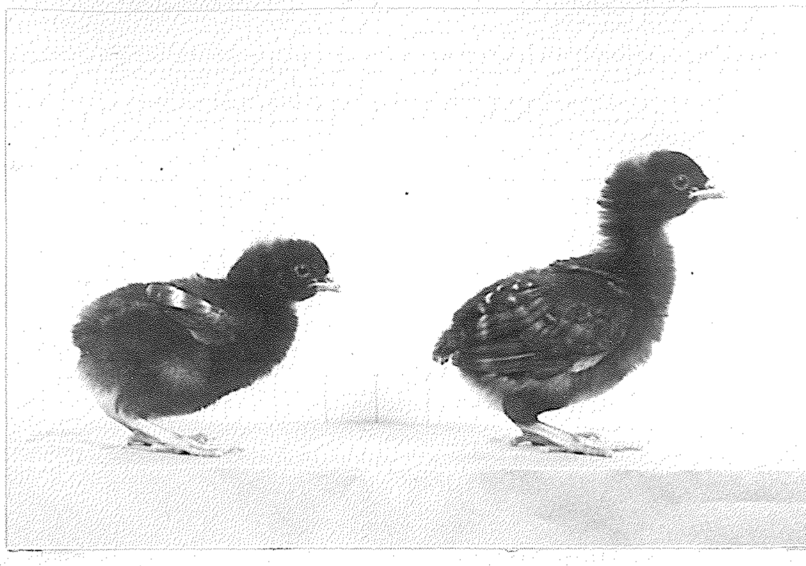

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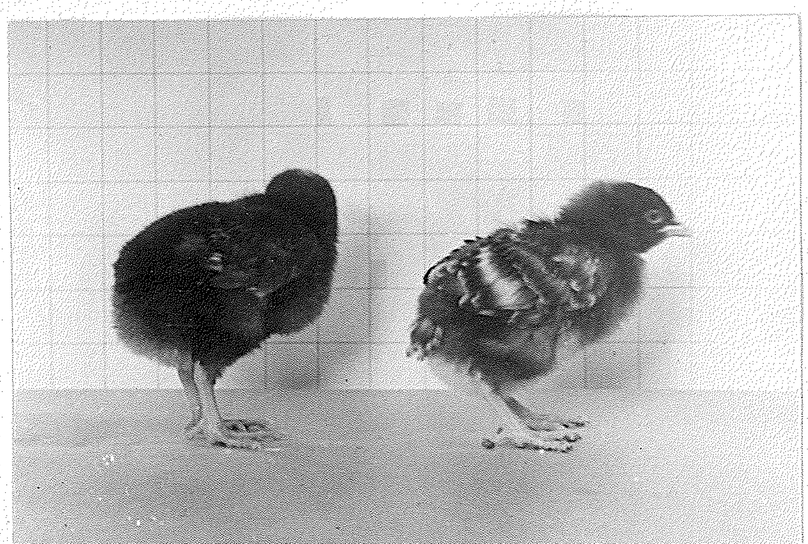

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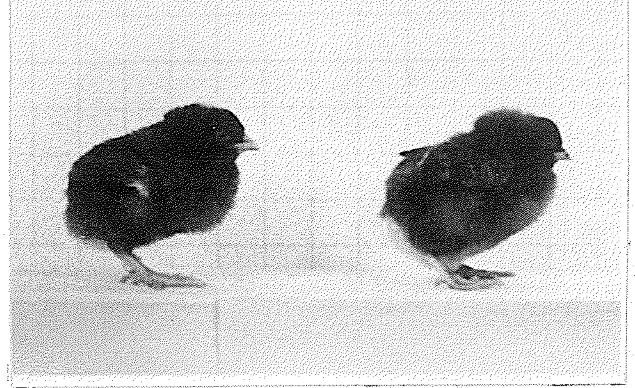

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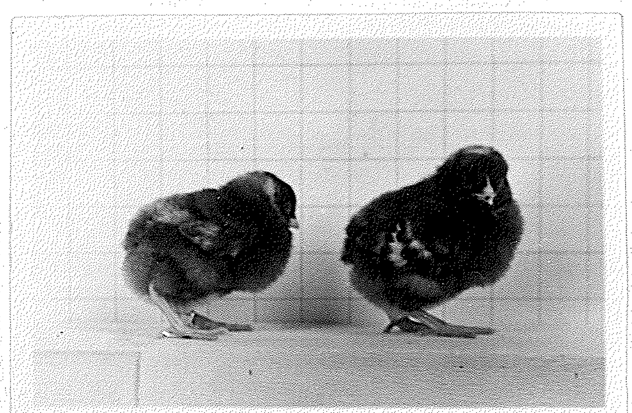
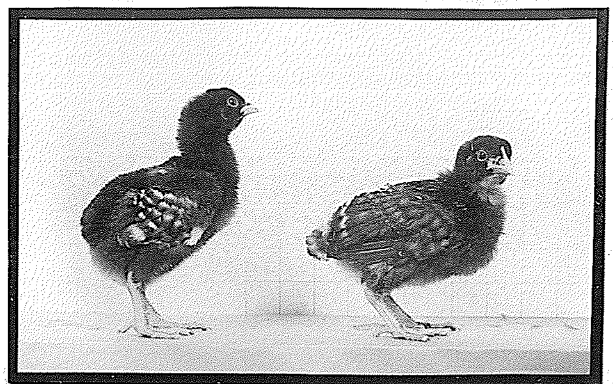


Figure 7.

Figure 8.



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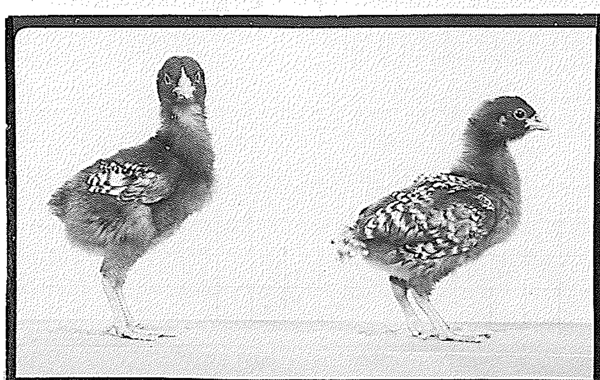


Figure 10.

In 1939 the heterozygous male (S s) was mated to late feathering females (S -). Half of the female progeny from the above mating were early feathering (s -) and the other half late feathering (S -). In the case of the male progeny, one half were homozygous late feathering (S S), and the other half heterozygous (S s) for this factor. In 1940 a mating of the S s males with s - females produced the following progeny: males 1/2 S s and 1/2 s s; females S - and s -, also in a 1:1 ratio. The following year homozygous males (s s) were mated with the "hemizygous" females (s -), the male and female progeny being pure for the sex-linked early-feathering factor.

The study of the rate of feathering is based on three generations of chickens obtained in the course of developing a pure sex-linked early feathering strain of Barred Plymouth Rocks. The population in 1942 also included those chicks hatched from two R. O. P. strains of Barred Plymouth Rocks. It was interesting to note that of the 164 chicks hatched from the above mentioned R.O.P. eggs, two females were early feathering for the sex-linked gene, indicating its presence in normal strains of this breed.

Classification into early feathering for the above mentioned factor, was based on well developed primary wing feathers in day old chicks (figure 3), confirmed by the presence of tail feathers at 2 weeks of age (Fig.4 & 5). Figures 6 and 7 show both sexes of the two strains of Barred Plymouth Rock chicks at 1 week of age, when accurate classification is practically impossible. Figure 8 shows the early feathering Barred Rock chick at 2 weeks of age, compared with a New Hampshire chick (an early feathering breed) of the same age. In figures 9 & 10 the two strains of Barred Plymouth Rocks are compared at 3 weeks of age. The appearance of tail feathers in many of the late feathering individuals makes classification difficult at this stage.

Prospective sires of unknown genetic constitution were tested for the sex-linked factor in question, by stud-mating them before the regular breeding season. This was done by mating individual males with genetically known females and examining their progeny at one day of age and again at 2 weeks as outlined above. Sexing of day-old chicks was done by the method described by Jerome (1939), using character of head spot, shank and foot color, and down color.

I. Genetic Study of Sex-Linked Early Feathering.

1. Single Recessive Factor Inheritance

To establish a basis for the study undertaken, it was necessary to ascertain if the early-feathering factor, introduced into the University stock, was governed by the single recessive sex-linked gene described by Serebrovsky (1922) and other workers. Hays (1932), working with Rhode Island Reds, obtained very close agreement between the actual and expected ratios of early and late feathering in chicks of both sexes. Results obtained in the present study with Barred Plymouth Rocks are shown in Tables 1 and 2.

The actual and expected ratios were tested for goodness of fit by the Chi-square method, as described by Goulden (1939). The probability (P) values were obtained from Fisher's (1934) table of Chi-square. With two exceptions there was close agreement between the actual and expected ratios. The first tendency towards disagreement, occurred in the 1941 female progeny resulting from the mating of a heterozygous late feathering male (Ss) with late feathering females (S -). Similarly in 1942 there was a significant discrepancy between the actual and expected ratios in the

TABLE 1.

Actual and Expected Ratios of Early and Late Feathering Progeny.

Year	Matings		Progeny						
	Sire	Dam	Sex	Ph.	Gen.	a	t	X^2	P values
1940	Ss	S-,s-	F	Early	s-	57	54	.332	.50 - .70
				Late	S-	51	54		
1941	Ss	S-	F	Early	s-	59	70	3.44	.05 - .10
				Late	S-	81	70		
	Ss	s-	F	Early	s-	61	63.5	.18	.50 - .70
				Late	S-	66	63.5		
	ss	S-	F	Early	s-	23	25	.16	.50 - .70
				Late	S-	2	0		
	ss	s-	F	Early	s-	8	9	.11	.70 - .80
				Late	S-	1	0		
	ss	s-	M	Early	ss	8	8	0	
				Late	SS,Ss	0	0		
1942	ss	s-	M	Early	ss	130	158	4.9	.02 - .05
				Late	SS,Ss	28	0		
	ss	S-,s-	F	Early	s-	292	310	1.04	.30 - .50
				Late	S-	18	0		

Key to Tables 1 and 2.

F	-	female	Gen.	-	genotype
M	-	male	a	-	actual
Ph	-	phenotype	t	-	expected

male progeny from a homozygous early feathering male (ss) on early feathering females (s-). In both cases there was a preponderance of late feathering individuals. This may have been due to the presence of an autosomal "retarded" factor (see Section I , 2b).

TABLE 2.

1941 Actual and Expected Ratios of Early and Late Heterozygous Male Progeny.

Mating		Progeny						
Sire	Dam	Sex	Ph.	Gen.	a	t	X^2	P values
Ss	S-	M	Early	ss	2	0	.02	.80 - .90
			Late	SS,Ss	140	142		
Ss	s-	M	Early	ss	55	55	0	
			Late	Ss	55	55		
ss	S-	M	Early	ss	2	0	.12	.70 - .80
			Late	Ss	31	33		
ss	S-	M	Early	ss	1	0	.008	.90 - .95
			Late	ss	120	121		

The possibility of incomplete dominance of the sex-linked late-feathering factor arises in heterozygous males (Ss). The author experienced difficulty in classifying certain males for the sex-linked factor on the basis of primary wing feather development in day-old chicks. The wing of one such typical heterozygous male, at one day of age, is shown in fig. 3, No. 2, compared with wings of homozygous late and early feathering males. In such cases the final decision was made at two weeks of age, and in 85 per cent. of cases the intermediate types of day-old, were classed as late feathering at two weeks of age. That this was in general the correct designation, is indicated by the close agreement of expected and obtained ratios in Table 2.

2. Modified Expressions of Sex-Linked Early-Feathering Factor.

(a) Somatic Inhibiting Effect.

Danforth (1929) found, in addition to the sex-linked gene, another factor capable of producing "slow" feathering in Barred Plymouth Rocks. This was an indirect inhibiting effect, thought to be an hereditary endocrine or metabolic trait. In the present study a comparison of the rate of feathering was made between the early feathering Barred Plymouth Rock chicks and the New Hampshire chicks which are normally early feathering. There appeared to be some difference in the development of the primary wing feathers between the two types at one day of age (fig. 11) At two weeks of age (fig. 8) the difference in length of wing and tail feathers, though very small, still persisted, those of the Barred Plymouth Rocks being shorter. This appeared to be the same inhibiting effect as that described by Danforth.

(b) Retarded Feathering.

Detection of homozygous early feathering chicks at two weeks of age, is further complicated by the presence of an autosomal recessive "retarded" factor. According to Warren (1933) it is expressed in day-old chicks by retarding the development of the secondary flight feathers with the exception of the first three, whereas at 10 days of age it prevents the development of the tail feathers and the above mentioned secondaries. This was later confirmed by McClary and Bearse (1941), and by Darrow (1942). Examination of one lot of early feathering Barred Plymouth Rock chicks in 1943, indicated that about 9 per cent of them carried the retarded factor (fig. 12). However, since it has no effect on the primary wing feather development, it would not influence the accuracy of classification of day-old chicks into early and late feathering types.

The early-feathering factor, introduced into the University Barred Plymouth Rocks, has been shown to result

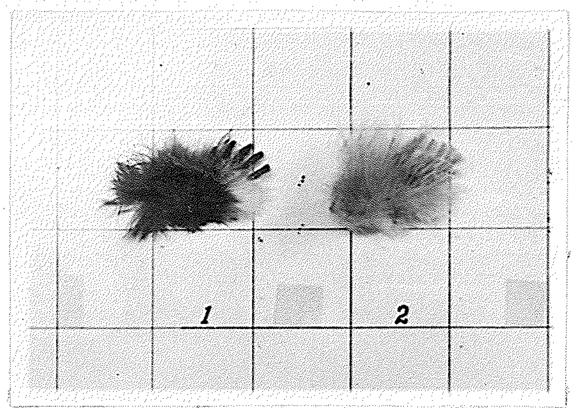


Figure 11.

Figure 12.

from a single sex-linked recessive gene. The expression of this factor is influenced by a retarding gene, presumably an autosomal recessive, which interferes with classification of early and late feathering at two weeks of age. Furthermore there appear to be a few cases of incomplete dominance of late feathering in day-old, heterozygous male chicks. A strain can be purified for sex-linked early feathering on the basis of primary wing feather development of day-old chicks. To eliminate the autosomal recessive retarded factor, would necessitate critical test matings of all breeding stock to known retarded individuals, in order to reveal the presence of this recessive trait in the breeding stock.

II. Comparison Between Early and Late Sex-Linked Feathering.

1. Growing Stock

(a) Weights of day-old chicks.

Since, as shown later (II, 1 d), a relation exists between rates of growth and feathering of chicks, one might expect differences in weight of early and late feathering chicks at day-old. However a high correlation is known to exist between weight of egg set and weight of chick hatched, as confirmed by Munro and Kosin (1940), and previously established by other workers.

Table 3 shows the analysis of weights of day-old female chicks, early and late feathering. In 1940 the egg weight factor was eliminated since the use of the heterozygous males resulted in early and late feathering female progeny in roughly equal numbers from each hen in each hatch. There was no significant difference in chick weights. The 1942 portion of Table 3 compares the day-old weights of pure early feathering and unrelated late feathering females, again with no significant difference.

Table 4 shows the results obtained in 1942, comparing weights of day-old male chicks. The heterozygous males are in an intermediate position between the homozygous males

TABLE 3.

Weights, in Grams, of day-old Females.

	Mean Weights				Mean		
	Early	(No.)	Late	(No.)	Difference	t value	P value
1940	41.50	(63)	41.20	(57)	0.30 ± .64	0.468	.60 - .70
1942	42.46	(78)	42.06	(82)	0.40 ± .42	0.952	.30 - .40

TABLE 4.

1942 Weights, in Grams, of day-old Males.

		Mean	Mean		
Genotype	(No.)	Weights	Difference	t value	P value
ss	(76)	43.96	0.68 ± .497	1.36	.10 - .20
Ss	(118)	43.28			
ss	(76)	43.96	1.14 ± .516	2.20	.02 - .05
SS	(78)	42.82			
Ss	(118)	43.28	0.46 ± .525	0.876	.30 - .40
SS	(78)	42.82			

with respect to weight at one day of age. No significant difference was found in comparing closely related pure early and heterozygous late feathering males. Likewise heterozygous slow and unrelated pure slow males showed no significant difference. But pure early males were slightly but significantly heavier than unrelated pure late feathering males. No definite conclusion can be drawn from the latter result, since a similar difference in day-old weights did not show in the comparisons with female chicks.

(b) Feather development.

Sex-linked early feathering shows strikingly in the rapid growth of wing and tail feathers, except in the presence of the retarding genes previously mentioned. The question arises, to what extent does the sex-linked factor affect the development of feathers on other parts of the body?

Radi and Warren (1938) established strains of Rhode Island Reds, genetically different for degree of broiler feathering, and suggest that these differences were probably due to modifying factors acting upon the sex-linked dominant late-feathering gene. According to the above workers there is evidence of physiological relationship between these two types of feathering. Darrow (1941) showed that, at six weeks, there was some degree of association between the greater number and length of primary wing feathers and the better feathering score on the back. He concluded that probably the highest correlation was between well developed tails at 10 days and good back feathering at 6 weeks of age.

In 8 years of selective breeding of Rhode Island Reds, based solely on back feathering at 8 weeks of age, Hays and Sanborn (1942) produced a strain which was pure for the above trait. This same strain increased automatically in the percentage of individuals showing the sex-linked type of "rapid" feathering, males by 60 per cent and females by 77 per cent, in eight generations. The authors concluded that the sex-linked early feathering gene, at least in a heterozygous condition, is essential for complete back feathering at eight weeks of age. They also observed that, when males were selected only on the basis of feather development at 8 weeks of age, progress was very slow in breeding for rapid back feathering.

In 1940 detailed weekly records were kept to eight weeks of age on feather development in the females. Measurements were made of the length of primary wing feathers, main tail feathers, and feathers in the pectoral region. Estimates also were made of the percentage of feathering in the breast, back and pectoral regions. The results are presented graphically in figures 13 to 18.

TABLE 5.

Summary of Feather Development in Females.

	Length of Feathers at 6 weeks			Degree of Feathering at 8 weeks		
	Wing M.M.	Tail M.M.	Pectoral M.M.	Breast %	Pectoral %	Back %
Mean (s+)	92.38	56.69	41.62	62.62	76.95	91.93
" (S-)	86.00	14.35	37.56	48.04	64.13	72.61
Difference	6.38	42.34	4.05	14.58	12.82	19.32
St. Error	± 1.81	±2.01	± 1.52	± 3.97	± 4.15	± 3.94
t value	3.51	21.08	2.67	3.67	3.09	4.90
P value	- - - - - All P values are less than .01 - - - -					

Statistical analysis of the same data (Table 5) shows that at 8 weeks of age there was a significant difference in favour of the sex-linked early feathering females in percentage feathering over the breast, back and pectoral region. Similarly there was a significant difference between the two types of females in length of primary wing feathers, tail feathers and pectoral feathers at six weeks of age. From the graphs it is evident that the difference in length of wing

Figure 13.

Length of Primary Wing Feathers in Females at 1 - 8 Weeks of Age.

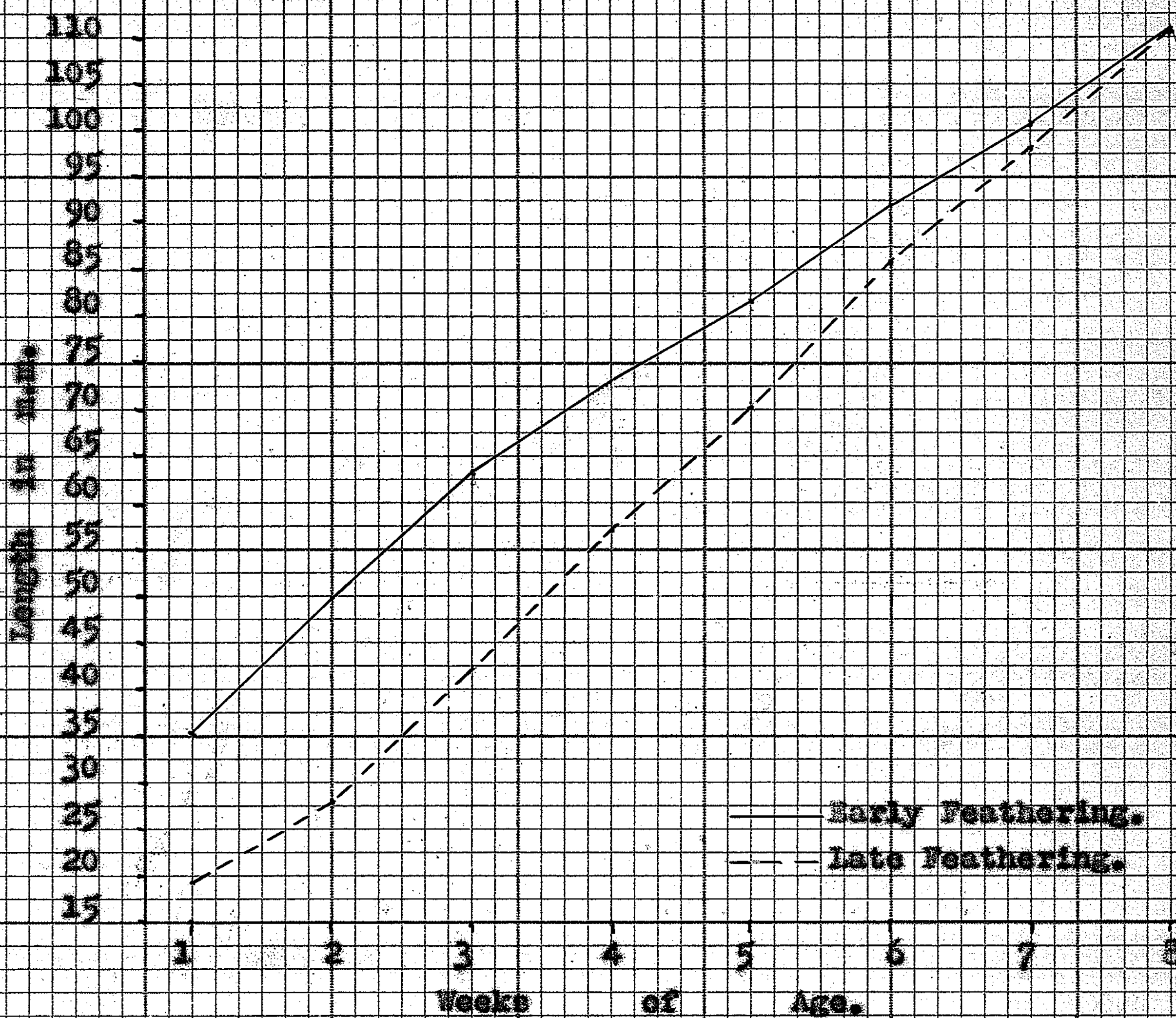


Figure 14.

Length of Primary Tail Feathers in Females at 2 - 8 Weeks of Age.

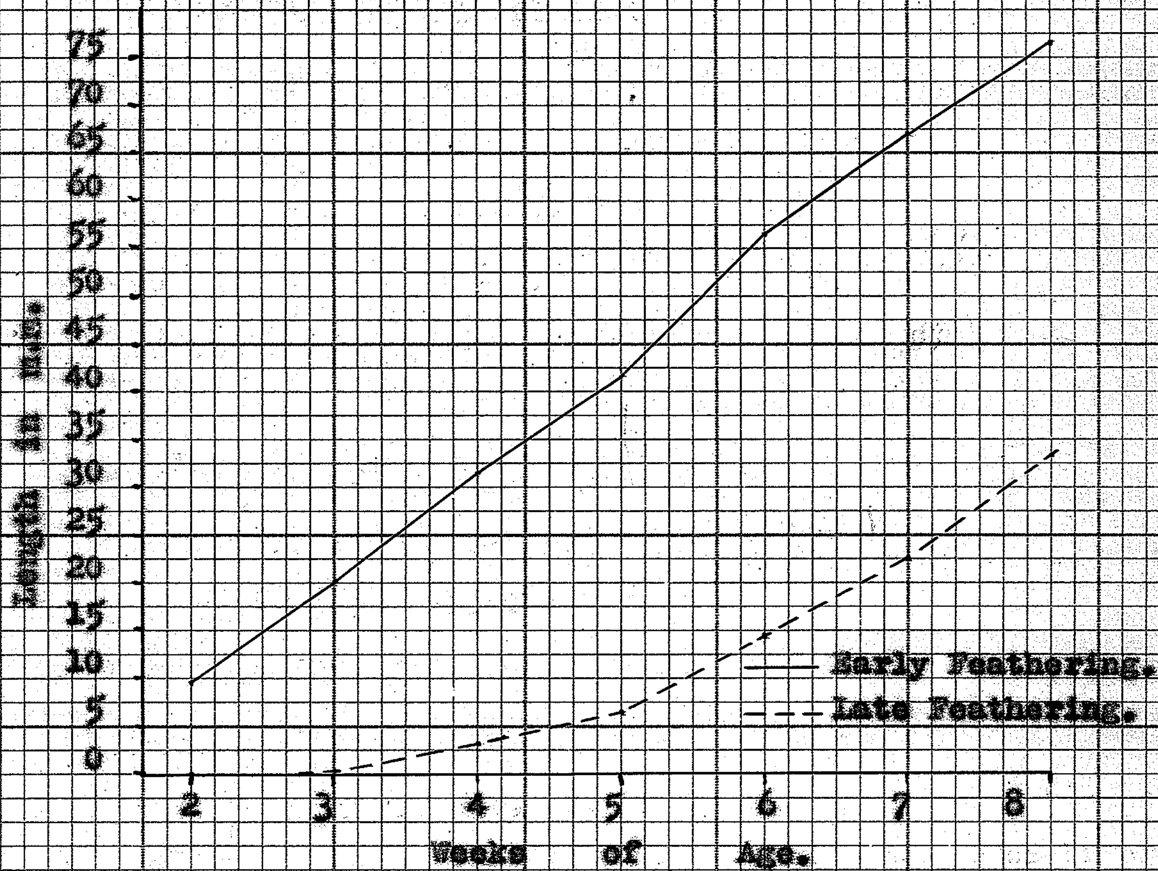


Figure 15.

Length of Pectoral Feathers in Females at 3 - 8 Weeks of Age.

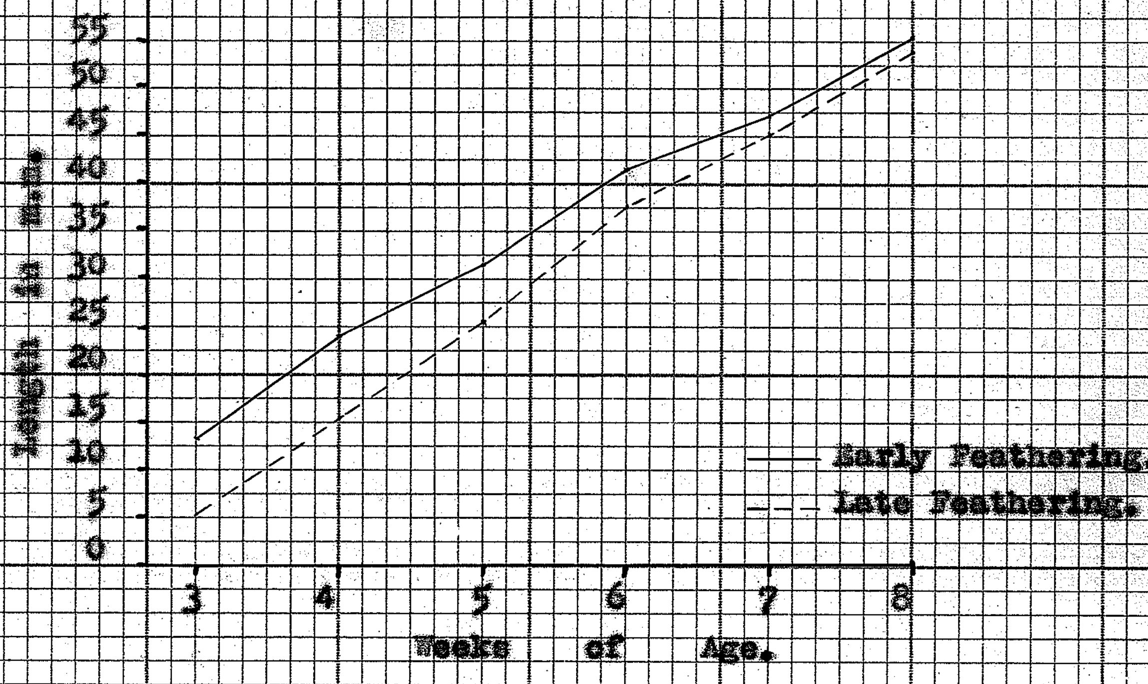


Figure 16.

Percentage of Breast Feathering in Females at 4 - 8 Weeks of Age.

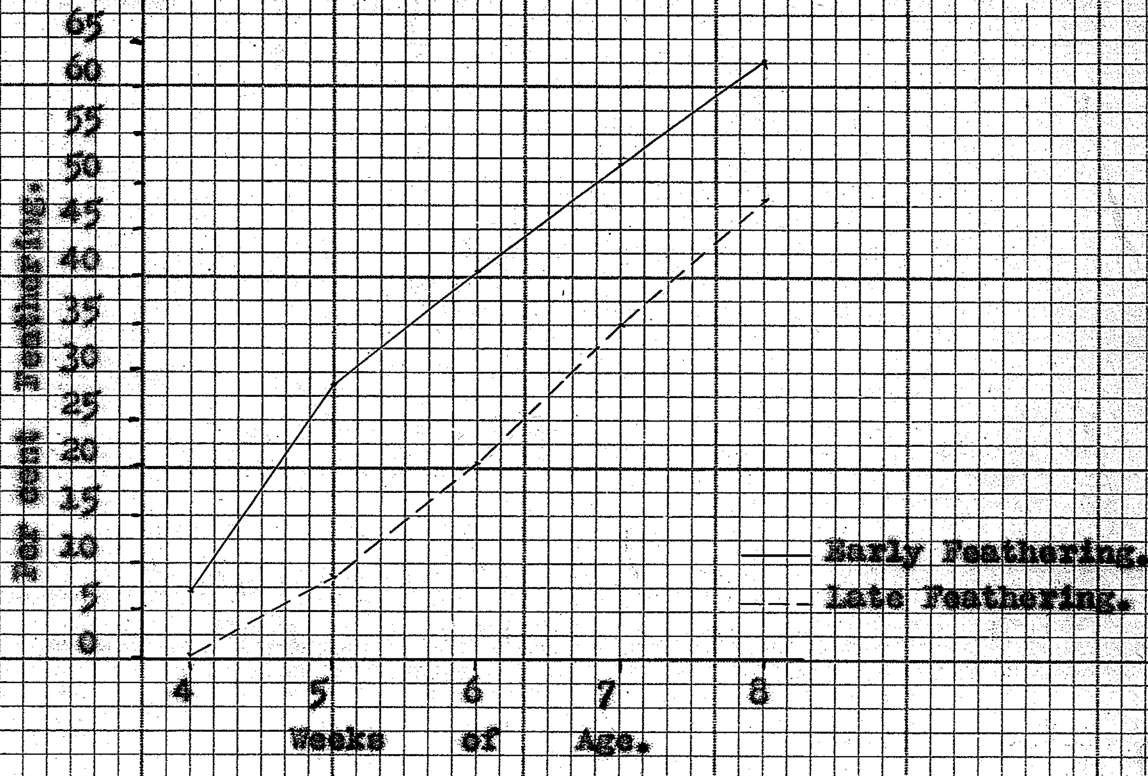


Figure 17.

Percentage of Pectoral Feathering in Females at 4 - 8 Weeks of Age.

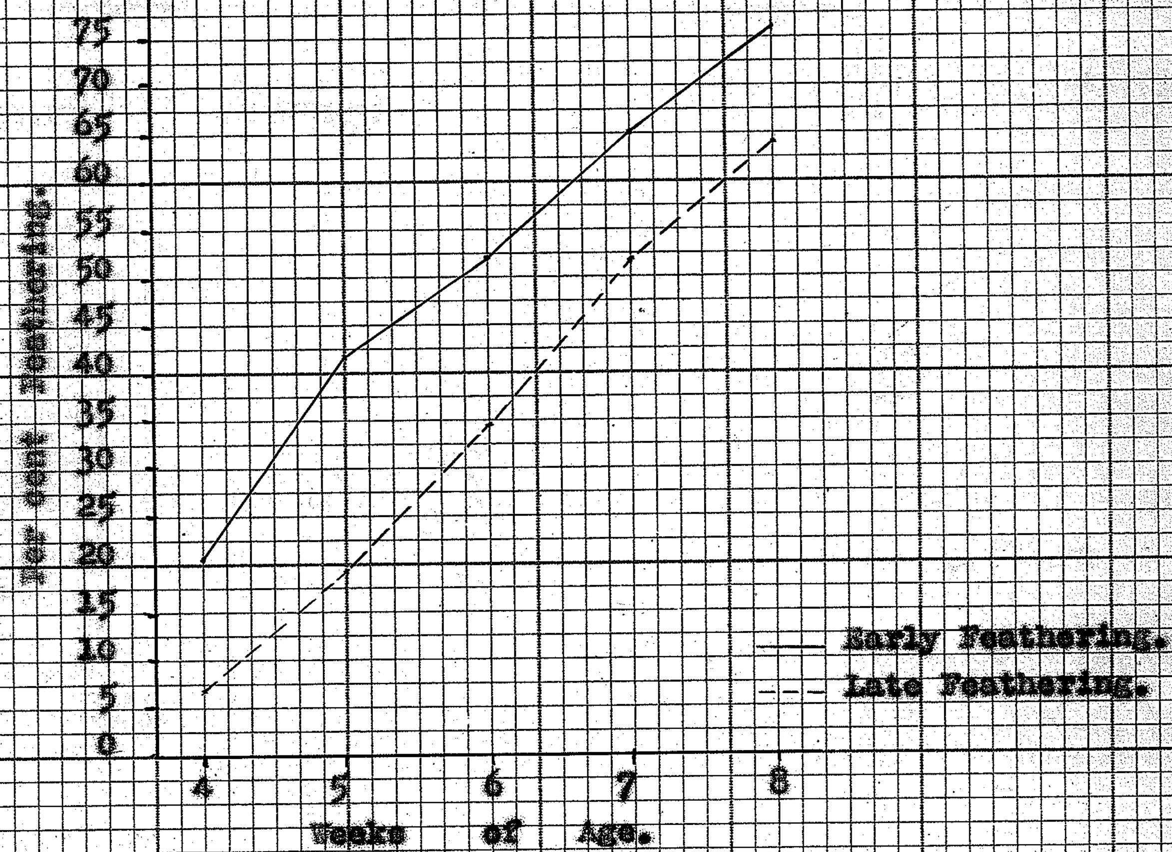
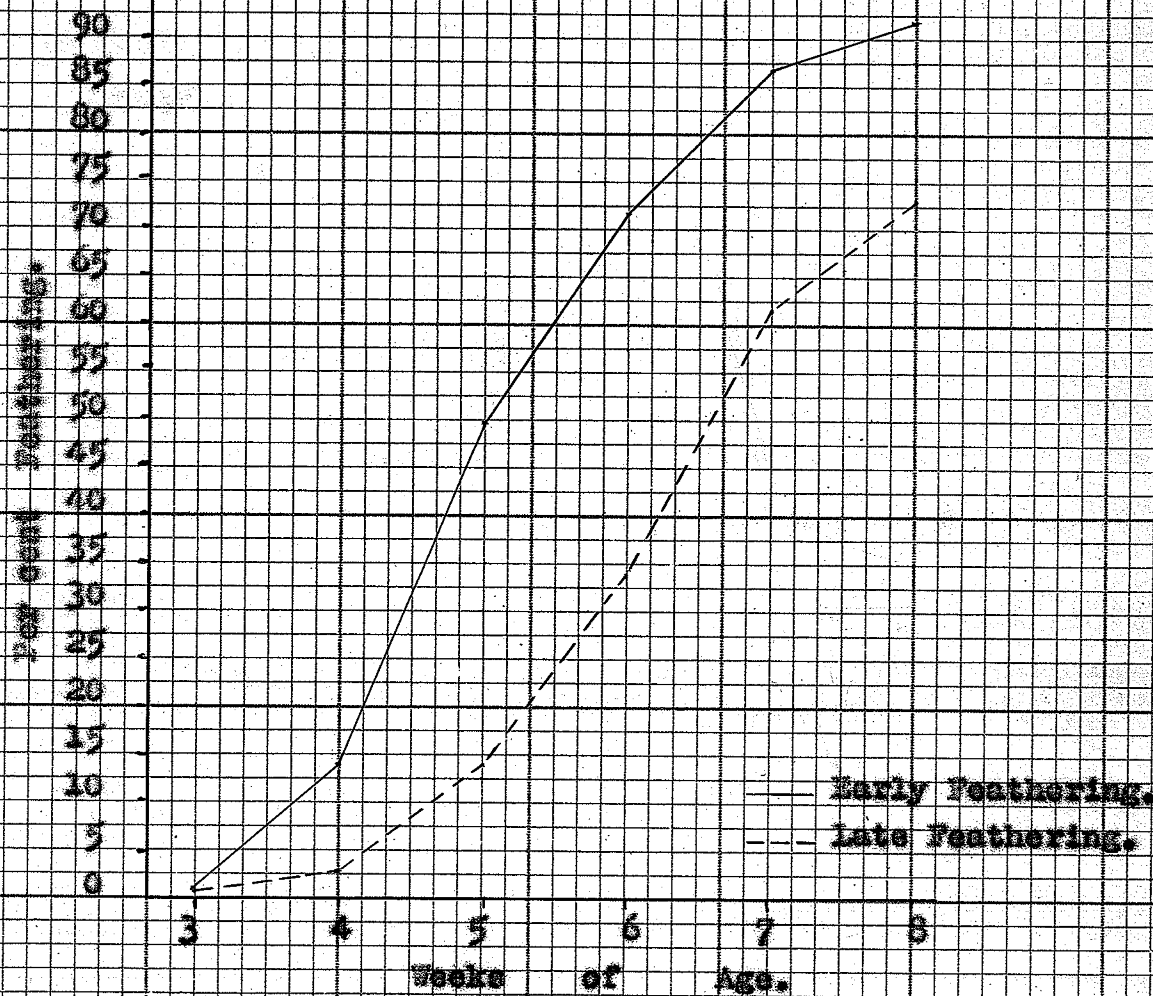


Figure 18.

Percentage of Back Feathering in Females
At 3 - 8 Weeks of Age.



feathers (fig.13), and also of pectoral feathers (fig.15), decreased gradually until at 8 weeks of age there was no difference in the case of the former. On the other hand the difference in length of tail feathers (fig.14) increased gradually until at 8 weeks the length of tails of the early feathering strain was more than double that of the late feathering females. This is possibly what Lloyd (1939) was referring to when he stated that classification of young cockerels was not possible on the basis of feather growth, until 8 weeks of age.

Results of the present study indicate clearly that the rate of feathering over the body generally, to 8 weeks of age, is distinctly associated with the sex-linked early-feathering factor. Reasonably accurate classification into early and late feathering types on the basis of length of tail feathers, is possible at 5 to 8 weeks.

(c) Body Weight and Feather Development.

Gericke and Platt (1932) obtained a significant correlation between body weight and feather development at 8 weeks of age in the case of Barred Plymouth Rocks. On the other hand Jaap and Morris (1936) obtained a rather low degree of correlation between weight and feathering at 8 weeks.

The two genetic groups, early and late feathering, were studied separately with respect to body weight and

Figure 19.

Correlation Between Body Weight and Length of Primary Wing Feathers in Early Feathering Females at 8 Weeks of Age.

Body Weight in Pounds.

Length in m.m.	0.60 to 0.79	0.80 to 0.99	1.00 to 1.19	1.20 to 1.39	1.40 to 1.59	1.60 to 1.79	Total
91-95	1						1
96-100	0						0
101-105		4	2				6
106-110		5	4	2	2		13
111-115			5	6	4		15
116-120				3	2		5
121-125						1	1
Total	1	9	11	11	8	1	41

r = .719

t = 6.458

P = less than .01

Figure 20.

Correlation Between Body Weight and Length of Primary Wing Feathers in Late Feathering Females at 8 Weeks of Age.

Body Weight in Pounds.

Length in m.m.	0.60 to 0.79	0.80 to 0.99	1.00 to 1.19	1.20 to 1.39	1.40 to 1.59	1.60 to 1.79	Total
91-95	2						2
96-100	1		1				2
101-105		1					1
106-110	1	2		1			4
111-115		1	1	3			5
116-120			5	2	1		8
121-125						1	1
Total	4	4	7	6	1	1	23

r = .723

t = 4.79

P = less than .01

Figure 21.

Correlation Between Body Weight and Length of Main Tail Feathers in Early Feathering Females at 8 Weeks of Age.

Body Weight in Pounds.

Length in m.m.	0.60 to 0.79	0.80 to 0.99	1.00 to 1.19	1.20 to 1.39	1.40 to 1.59	1.60 to 1.79	Total
51-60	1	2		1			4
61-70		2	2	1	1		6
71-80		4	6	7	2		19
81-90		1	3	2	4		10
91-100					1	1	2
Total	1	9	11	11	8	1	41

$r = .506$

$t = 3.662$

$P =$ less than .01

Figure 22.

Correlation Between Body Weight and Length of Main Tail Feathers in Late Feathering Females at 8 Weeks of Age.

Body Weight in Pounds.

Length in M.M.	0.60 to 0.79	0.80 to 0.99	1.00 to 1.19	1.20 to 1.39	1.40 to 1.59	1.60 to 1.79	Total
11-20	1	1					2
21-30	2	3	1	1	1		8
31-40			5	3			8
41-50	1		1	2			4
51-60						1	1
Total	4	4	7	6	1	1	23

r = .532

t = 2.876

P = less than .01

Figure 23.

Correlation Between Body Weight and Percentage of Pectoral Feathering in Early Feathering Females at 8 Weeks of Age.

Body Weight in Pounds.

Per cent Feathering	0.60 to 0.79	0.80 to 0.99	1.00 to 1.19	1.20 to 1.39	1.40 to 1.59	1.60 to 1.79	Total
51-60	1	3	1				5
61-70		5	5	4			14
71-80		1	2	1	2		6
81-90			3	4	4	1	12
91-100				2	2		4
Total	1	9	11	11	8	1	41

r = .677

t = 5.74

P = less than .01

Figure 44.

Correlation Between Body Weight and Percentage of Pectoral Feathering in Late Feathering Females at 8 Weeks of Age.

Body Weight in Pounds.

Per cent Feathering	0.60 to 0.79	0.80 to 0.99	1.00 to 1.19	1.20 to 1.39	1.40 to 1.59	1.60 to 1.79	Total
11-20	1						1
21-30		1					1
31-40		1	1				2
41-50	2	1		1			4
51-60		1	2				3
61-70	1		1				2
71-80			2	1	1		4
81-90			1	3			4
91-100				1		1	2
Total	4	4	7	6	1	1	23

r = .702

t = 7.99

P = less than .01

Figure 25.

Correlation Between Body Weight and Percentage of Breast Feathering in Early Feathering Females at 8 Weeks of Age.

Body Weight in Pounds.

Per cent Feathering	0.60 to 0.79	0.80 to 0.99	1.00 to 1.19	1.20 to 1.39	1.40 to 1.59	1.60 to 1.79	Total
41-50	1	6	3	2			12
51-60		2	3	2			7
61-70		1	5	5	3		14
71-80				1	4	1	6
81-90				1	1		2
Total	1	9	11	11	8	1	41

r = .695

t = 6.03

P = less than .01

Figure 26.

Correlation Between Body Weight and Percentage of Breast Feathering in Late Feathering Females at 8 Weeks of Age.

Body Weight in Pounds.

Per cent Feathering	0.60 to 0.79	0.80 to 0.99	1.00 to 1.19	1.20 to 1.39	1.40 to 1.59	1.60 to 1.79	Total
1-10	1						1
11-20			1				1
21-30	1	3					4
31-40	1		1	1			3
41-50		1	1	1			3
51-60			2	2			4
61-70		1	2	1			4
71-80				1	1		2
81-90						1	1
Total	3	5	7	6	1	1	23

$r = .710$

$t = 4.61$

$P =$ less than .01

Figure 27.

Correlation Between Body Weight and Percentage of Back Feathering in Late Feathering Females at 8 Weeks of Age.

Body Weight in Pounds.

Per cent Feathering	0.60 to 0.79	0.80 to 0.99	1.00 to 1.19	1.20 to 1.39	1.40 to 1.59	1.60 to 1.79	Total
31-40	1	1					2
41-50		1	1				2
51-60	2		1	1			4
61-70		1					1
71-80		1	1	1	1		4
81-90	1		2	2			5
91-100			2	2		1	5
Total	4	4	7	6	1	1	23

r = .537

t = 2.916

P = less than .01

Figure 28.

Correlation Between Body Weight and Percentage of Back Feathering in Early Feathering Females at 8 Weeks of Age.

Body Weight in Pounds.

Per cent Feathering	0.60 to 0.79	0.80 to 0.99	1.00 to 1.19	1.20 to 1.39	1.40 to 1.59	1.60 to 1.79	Total
61-70				1			1
71-80		2	1				3
81-90	1	2	4	1			8
91-100		5	6	9	8	1	29
Total	1	9	11	11	8	1	41

r = .338

t = 2.24

P = .02 - .05

feathering at 8 weeks of age. Figures 19, 21, 23, 25, and 27 show the correlations obtained between body weight and feather development in five regions of the body of early feathering pullets. Data for the late feathering pullets are shown in figures 20, 22, 24, 26, and 28. In all cases there was a positive and highly significant correlation between feather development and body weight at eight weeks of age. These results are summarized in Table 6.

TABLE 6

Summary of Correlations

	Length of Feathers		Per cent feathering		
	Wing	Tail	Pectoral	Breast	Back
Early - r	.719	.506	.677	.695	.538
- P	- - - - - - less than .01 - - - - - -				.02 - .05
Late - r	.723	.532	.702	.710	.537
- P	- - - - - - less than .01 - - - - - -				- - - - -

(d) Rate of Growth.

Maw (1935) found a relation between factors for size and two sex-linked characters, colour of plumage and rate of tail feathering, in crosses between Light Brahmas and Golden Sebright Bantams. The following study deals with the effect of the sex-linked type of feathering on the rate of growth in Barred Plymouth Rocks.

In 1940 the females of five hatches were weighed at 2, 4, 6 and 8 weeks. It has been shown previously (Table 3) that day-old chick weight differences between the early and late feathering groups were insignificant in 1940. According to the analysis of variance (method used is described by Yates, 1934) there was no significant difference in weight between the early and late feathering types at 2 weeks of age (table 7). At 4 weeks (table 8) the difference approached significant proportions, while at 6 and 8 weeks of age (tables 9 and 10), the F values obtained were well beyond the 5 per cent point of F, indicating that the early feathering group was significantly heavier.

The females of a later hatch were weighed weekly up to 21 weeks of age. According to the graph (fig. 29), there was a weight difference up to about 16 weeks of age, the early feathering females being heavier. However, from 19 to 21 weeks the situation was reversed in favor of the late feathering birds. Statistical analysis of the same data (table 11) reveals that the differences observed at 8, 16, and 21 weeks of age were insignificant. In 1942

TABLE 7

1940 Weights of Five Hatches of Female Chicks at 2 Weeks of Age.

Hatches	1	2	3	4	5	Total
No. of chicks - E.	71	23	15	26	43	178
" " " - L.	42	20	24	18	26	130

Analysis of Variance.

	D.F.	S.S.	M.S.	F	5% F
E.L. uncorrected	1	656.94			
Pairs corrected	4	6,701.56			
Total constants	5	7,358.50			
Pairs uncorrected	4	6,795.60			
E.L. corrected	1	562.90	562.90	2.41	3.87
Total constants	5	7,358.50			
Interaction	4	280.00			
Between hatches	9	7,638.50			
Within (error)	298	69,523.32	233.29		
Total	307	77,161.82			

Key to tables 7, 8, 9 and 10

E - early feathering.
L - late feathering.
D.F. - Degrees of Freedom.
S.S. - Sums of Squares.
M.S. - Mean Square.
F - Test of significance described by Goulden (1934).

TABLE 8

1940 Weights of Five Hatches of Female Chicks at 4 Weeks of Age.

Analysis of Variance.

	D.F.	S.S.	M.S.	F	5% F
E.L. uncorrected	1	5,443.27			
Pairs corrected	4	40,311.30			
Total constants	5	45,754.57			
Pairs uncorrected	4	40,336.08			
E.L. corrected	1	5,418.49	5,418.5	3.7	3.87
Total constants	5	45,754.57			
Interaction	4	3,437.76			
Between hatches	9	49,192.33			
Within (error)	298	436,056.35	1,463.2		
Total	307	485,248.68			

Population numbers are the same as in table 7

TABLE 9

1940 Weights of Five Hatches of Female Chicks at 6 Weeks of Age.

Analysis of Variance.

	D.F.	S.S.	M.S.	F	5% F
B.L. uncorrected	1	20,420.05			
Pairs corrected	4	54,621.74			
Total constants	5	75,041.79			
Pairs uncorrected	4	56,341.61			
B.L. corrected	1	18,700.18	18,700.18	4.10	3.87
Total constants	5	75,041.79			
Interaction	4	16,836.35			
Between hatches	9	91,878.14			
Within (error)	298	1,358,122.06	4,557.46		
Total	307	1,450,000.20			

Population numbers are the same as in table 7.

TABLE 10

1940 Weights of Five Hatches of Female Chicks at 8 Weeks of Age.

Analysis of Variance.

	D.F.	S.S.	M.S.	F	5% F
E.L. uncorrected	1	65,128.77			
Pairs corrected	4	223,524.36			
Total constants	5	288,653.13			
Pairs uncorrected	4	213,125.02			
E.L. corrected	1	75,528.11	75,528.11	6.45	3.87
Total constants	5	288,653.13			
Interaction	4	45,899.89			
Between hatches	9	344,553.02			
Within (error)	298	5,467,609.38	11,465.0		
Total	307	5,822,162.40			

Population numbers are the same as in table 7.

Figure 29.

Rate of Growth in Females at 1 - 21 Weeks of Age.

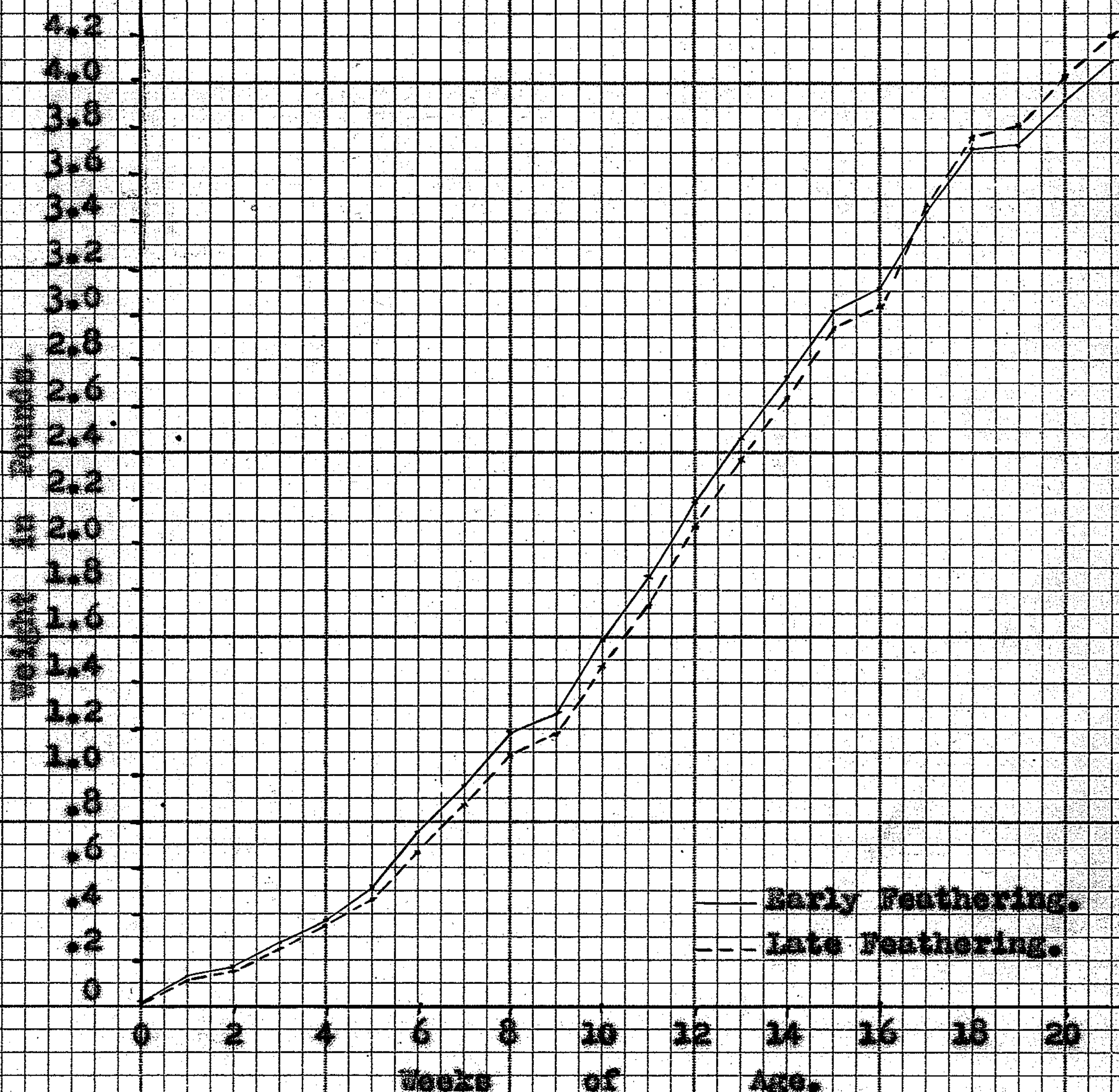


TABLE 11

1940 Body Weights (lbs) of Females

Age	Mean Weights: Early (41)	Mean Weights: Late (33)	Mean Difference	t value	P value
8 weeks	1.180	1.098	.082 ± .195	.420	.60 - .70
16 weeks	3.114	3.030	.084 ± .108	.780	.40 - .50
21 weeks	4.095	4.200	.105 ± .121	.869	.30 - .40

TABLE 12

1942 Body Weights (gms) of Females

Age	Mean Weights: Early (176)	Mean Weights: Late (60)	Mean Difference	t value	P value
4 weeks	76.35	69.16	7.19 ± 4.97	1.44	.10 - .20
8 weeks	209.6	168.6	41.0 ± 12.79	3.20	less than .01

a similar study was conducted, using the University strain of sex-linked early feathering birds and unrelated late feathering Barred Plymouth Rock females, all reared together. Statistical analysis of the body weights (table 12) showed that the early feathering birds were significantly heavier at 8 weeks but not at 4 weeks of age. From data presented there appears to be a distinct difference in growth rate up to the broiler stage in favor of the sex-linked early feathering females.

Comparisons of weights of males were made at 4 and at 8 weeks of age in 1942. The ss and Ss males of the population were of the same University strain, whereas the SS males were of an unrelated strain of Barred Plymouth Rocks. However all three genetic types of males were hatched and reared under the same conditions. Statistical analysis (table 13) shows that there were no significant differences between the three feathering genotypes at 4 weeks of age. At 8 weeks, however, the ss and Ss males were significantly heavier than the SS males.

The fact that the heterozygous males (Ss) outweighed the homozygous males (ss and SS), leads to some interesting speculation. Rates of growth and of feathering are definitely associated, as shown by positive and significant correlations in the female chicks (table 3).

TABLE 13

Body Weights (gms) of Male Chicks 1942.

Age	Genotype	(No)	Mean Wts.	Mean Difference	t value	P value
4 weeks	ss	(59)	87.69	1.58 ± 5.90	0.267	.70 - .80
	Ss	(79)	86.11			
" "	Ss	(79)	86.11	3.10 ± 5.95	0.520	.60 - .70
	SS	(52)	89.21			
" "	ss	(59)	87.69	1.52 ± 6.17	0.246	.80 - .90
	SS	(52)	89.21			
8 weeks	ss	(59)	219.83	7.06 ± 19.86	0.355	.70 - .80
	Ss	(79)	226.89			
" "	Ss	(79)	226.89	43.24 ± 16.38	2.639	less than .01
	SS	(52)	183.65			
" "	ss	(59)	219.83	36.18 ± 15.48	2.34	.01 - .02
	SS	(52)	183.65			

Possibly the S and s genes exert stimulating but different effects on growth in general, the influence of s being stronger, but S and s together exert a greater influence than either of the homozygous combinations alone. Could this be due to heterosis, through the combined effect of two different factors affecting growth?

(e) Mortality.

Records of the mortality in females of four different hatches were kept to 5 months of age in both 1940 and 1941. Runts and weaklings were killed and included in the mortality figures. In all cases early and late feathering types were hatched, brooded and reared together in each lot. Heavy losses were encountered in 1941 due to accidental chilling of the chicks and infection with cecal coccidiosis. Under such unfavorable conditions one might expect inherent weaknesses to show up more than they would normally. However no studies were made on the growing chicks in 1941. In each of the two years the per cent. mortality and the Chi-square test (table 14) show that there were no significant differences in mortality between the early and late feathering females up to 5 months of age.

In 1942 similar data were recorded on males. The ss and Ss birds were of the same University strain, whereas the SS males came from an unrelated strain of

TABLE 14

Mortality of Female Chicks up to 5 Months

	1940			1941		
Type	Alive	Dead	% Dead	Alive	Dead	% Dead
Early	159	23	12.6	121	92	43.2
Late	149	28	15.8	115	91	44.4
X^2 = 0.0109; P = .90 - .95				X^2 = 0.508; P = .30 - .50		

TABLE 15

Mortality of Male Chicks up to 5 Months in 1942.

Genotype	Alive	Dead	% Dead	X^2	P value
ss	52	21	28.7	0.777	.50 - .70
Ss	72	45	38.4		
Ss	72	45	38.4	3.59	.05 - .10
SS	39	44	53.0		
ss	52	21	28.7	8.422	.01 - .05
SS	39	44	53.0		

Barred Plymouth Rocks. All the chicks were hatched and reared together. Results obtained (table 15) show that there was a significantly higher rate of mortality among the homozygous late feathering males than in the homozygous early feathering group. The heterozygous cockerels were intermediate between the two homozygous groups of males with respect to mortality.

2. Mature Stock.

(a) Body Weight.

A relationship has been shown to exist between the sex-linked factors for feather development and body weight in the early growing stages (part II , 1 d). The question arises whether these sex-linked genes affect mature body weight. Weights of females hatched in 1940 and 1941 were recorded at 5 months and at 10 months of age.

Results obtained (table 16) show that the early feathering pullets in 1940 were significantly heavier at 5 months of age, but in 1941 the situation was reversed, the late feathering birds being significantly heavier. It would appear that environmental conditions favoured the early feathering birds one season and the late feathering group the next year.

The females were placed in winter quarters at five months of age, and distributed at random under similar conditions. Analysis of weights taken at 10 months of age (table 16), revealed that the differences observed previously were now insignificant for each of the two seasons. These results tend to confirm the previous suggestion that environmental conditions on the range were responsible for

TABLE 16

Body Weights (in pounds) of Females

	5 months of age		10 months of age	
	(No) 1940	(No) 1941	(No) 1940	(No) 1941
Mean - Early	(192) 4.23	(107) 4.116	(41) 6.51	(52) 6.917
" - Late	(201) 4.09	(108) 4.286	(29) 6.32	(46) 6.876
Difference	0.14 ± .054	0.17 ± .072	0.19 ± .141	0.041 ± .169
t value	2.607	2.35	1.347	0.243
P value	less than .01	.01 - .02	.10 - .20	.80 - .90

TABLE 17

1942 Body Weights (in pounds) of Males at 6 Months of Age.

Genotype (No)	Mean Wts	Mean Difference	t value	P value
ss (54)	6.50	.08 ± .200	.40	.60 - .70
Ss (23)	6.42			
ss (54)	6.50	.05 ± .139	.359	.70 - .80
SS (69)	6.55			
Ss (23)	6.42	.13 ± .194	.684	.40 - .50
SS (69)	6.55			

the statistically significant but contradictory findings at 6 months.

A similar study was made on the males in 1942 to detect any possible variations in body weight at 6 months which may be associated with genetic differences in rate of feathering. The two genetic types of males, ss and Ss were of the same University strain whereas the SS males were from an unrelated strain of Barred Plymouth Rocks. No significant differences were obtained (table 17).

(b) Quality of Barring.

In a study of Barred Plymouth Rocks, Martin (1929) concluded that there was a physiological linkage between quality of barring and slow rate of feathering. However he made no mention of the sex-linked factor as affecting the rate of feathering studied. It was later suggested by a group of workers at the Ontario Agricultural College (1938) that either a deficiency or an excess of protein, seemed to prevent the development of the barred feather pattern in Barred Plymouth Rocks. All chickens used in the present study were fed the same ration prepared at the University. The chick starter ration, in addition to the other essential ingredients, contained about 19 per cent protein, while the growing mash was somewhat lower in this nutrient.

During two consecutive years all the females were scored for quality of barring of the back, tail and wing feathers at 5 months of age (see Standard of Perfection, 1940). This was done on the basis of an arbitrary classification into A, B, and C in decreasing order of quality. The Chi-square test revealed a significant difference in the quality of barring of the tails (table 18) and wings (table 19) between the early and late feathering types during both seasons. The latter group had better quality of barring in these regions. With reference to barring over the back (table 20), there was no significant difference.

It appears that selection of exhibition Barred Plymouth Rock stock for distinctness of barring, may have been responsible, over a period of years, for the almost complete elimination of the naturally occurring sex-linked early-feathering factor from this breed.

TABLE 18

Quality of Barring of Tail Feathers.

	1940			1941		
Type	A	B	C	A	B	C
Early	17	111	60	11	74	23
Late	47	137	17	41	64	6
X^2 = 40.32 P = less than .01				X^2 = 27.92 P = less than .01		

TABLE 19

Quality of Barring of Wing Feathers

	1940			1941		
Type	A	B	C	A	B	C
Early	10	108	70	15	61	32
Late	26	136	39	28	69	14
	x^2 = 18.64 P = less than .01			x^2 = 11.40 P = less than .01		

TABLE 20

Quality of Barring of Back Feathers

	1940			1941		
Type	A	B	C	A	B	C
Early	41	124	23	23	69	16
Late	52	127	22	26	75	10
	x^2 = 0.68 P = .50 - .70			x^2 = 1.72 P = .30 - .50		

(c) Meat Type.

Due to the fact that the Barred Plymouth Rock is the most popular general purpose breed in Canada, meat production is an essential economic character of this breed. In the present undertaking the female population was examined at 5 months of age for condition of fleshing over the breast and back, as well as the shape and size of body. During two seasons the females were classified into A, B, and C on the basis of an arbitrary standard.

According to the Chi-square test (table 21) there was no significant difference in meat type between the two groups of females differing in the sex-linked rate-of-feathering factor.

TABLE 21

Meat Type of Females

	1940			1941		
	A	B	C	A	B	C
Early	96	80	16	74	32	2
Late	84	90	27	80	27	4
X^2 = 4.00 P = .10 - .20				X^2 = 1.20 P = .50 - .70		

(d) <u>Breast Blisters</u>.

Breast blisters may appear on the keel of the bird as fleshy growths under the skin, but more often as blisters filled with oily fluid or matter. The defect is noted particularly in chickens of roasting age, and such birds are seriously discriminated against by the dressed poultry trade. The Canadian dressed poultry regulations require that birds which have breast blisters, must be placed in "C" grade, and if badly discolored they must go in "No grade." According to a Canadian poultry magazine one of the large packing houses reported in 1940 that "seven per cent of the poultry received last season had breast blisters."

In 1940 a popular poultry magazine outlined a method of avoiding blisters by providing special rearing and roosting conditions on the range. Hodgson and Gutteridge (1941) followed specifically the instructions set out in that article, but their results indicated that roosting has little effect on the size or number of breast blisters. However they did find that rearing in wire-floored batteries for 12 weeks or more, definitely increases the number of blisters. They found, also, that battery rearing, in contrast with range rearing, produced more blisters in both sexes of all the breeds studied.

The above workers obtained evidence that a definite breed and sex difference exists in the occurrence of breast blisters. The males exhibited a much greater incidence than the females, and the Mediterranean breeds were more resistant to the condition than the American breeds. From the genetic point of view they concluded that the make up of the individual male apparently has some small influence on his progeny with regard to blister formation but that the mode of inheritance is complex.

Incidental to the present study of sex-linked rate of feathering, records were made on prevalence of breast blisters in chickens at 5 months of age. Hodgson and Gutteridge (1941) found that most of the breast blisters develop between 6 and 20 weeks of age but a few of them may not appear until the 22nd week. Examination at 5 months of age should, therefore, reveal all the blisters.

In 1941 only the University strain of Barred Plymouth Rocks was used in this study. These birds were all started under electric brooders, using straw for litter and providing roosting space at about 6 weeks of age. At 8 weeks of age the chickens were transfered to range shelters which were equipped with wire floors and roosts. The population was mixed for the sex-linked early-feathering factor. The following year the University early feathering strain was compared with unrelated late feathering Barred Plymouth Rocks. All the birds were hatched in the same incubator and started under the same conditions as the previous year, but at 8 weeks of age the chickens were transfered to colony houses equipped with wooden floors and roosts. Data accumulated during the two years, were analysed on the basis of blister incidence and the sex-linked feathering factor (table 22). Differences in breast blister incidence observed in 1941 and 1942 between the two feathering types, were not significant when the results were analysed separately for each sex. But, when the same data were combined for both sexes, the late feathering group showed a significantly greater degree of susceptibility to breast blisters than the early feathering type.

Records on the size of blisters were accumulated on the male population in 1942. It was believed that this information would reveal more accurately the relationship between breast blisters and the sex-linked rate of feathering. Statistical analysis of data, on the basis of size of blisters in cockerels (table 23), showed that the late feathering males were significantly more susceptible to blister development than the early feathering type.

TABLE 22.

Sex-linked Feathering in Relation to Breast Blister Incidence.

	Type	1942 Normal	1942 Blistered	1941 Normal	1941 Blistered
Female	Early	108	0	80	0
"	Late	110	1	11	1
	P is greater than .99			P = .19	
Male	Early	47	2	49	6
"	Late	169	18	93	19
	X^2 = 0.906 P = .30 - .50			X^2 = 0.642 P = .30 - .50	
Male &	Early	155	2	131	7
Female	Late	279	19	82	19
	X^2 = 5.45 P = .01 - .02			X^2 = 14.11 P = less than .01	

TABLE 23.

Sex-linked Feathering in Relation to
Incidence and Size of Breast Blisters in Males.

	Size of Breast Blisters			
Type	None	Small	Medium	Large
Early	49	3	2	1
Late	93	0	5	14

X^2 = 10.98 P = .01 - .02

The lower incidence of blisters in the early feathering birds suggests that this may be associated with breast feathering. It has been shown previously (table 8) that sex-linked early feathering females had a significantly higher percentage of breast feathering than the late feathering group at 8 weeks of age. Since males are more susceptible to blisters than females, information on percentage of breast feathering in the cockerels was considered essential. Analysis of the data for each sex separately and for both sexes combined (table 24) reveals that the early feathering type shows a significantly higher percentage of breast feathering, at 8 weeks of age, than the late feathering group.

TABLE 24.

Sex-linked Feathering in Relation to
Percentage of Breast Feathering in 1942

Sex	Type (No)	Mean % Feathering	Mean Difference	t value	P value
Males	Early (13)	59.6	24.2 ± 3.47	6.97	less than .01
"	Late (12)	35.4			
Female	Early (42)	62.6	14.6 ± 3.97	3.67	less than .01
"	Late (23)	48.0			
Male & Female	Early (55)	61.9	18.2 ± 3.39	5.37	less than .01
	Late (35)	43.7			

Evidence presented by this study appears to establish a relationship between the sex-linked early-feathering factor, early breast feathering and resistance to breast blisters in Barred Plymouth Rocks. This relationship is possibly physiological in nature. Early breast feathering, which is correlated with the sex-linked early-feathering gene, possibly offers some degree of protection at the critical stage and prevents the development of breast blisters. Furthermore, this relationship appears to account for the results obtained by Hodgson and Gutteridge (1941) that the Mediterranean breeds were more resistant to this defect than the American breeds of chickens. The former group is normally early feathering and the latter late feathering.

Sex difference in susceptibility to blisters, revealed by Hodgson and Gutteridge (1941), may also be explained on the basis of dimorphic feathering observed by Martin (1929). Data presented in table 25 confirm the fact that a significant sex difference existed in relation to blister incidence during both years studied. Furthermore, sex difference in relation to blister incidence may be accounted for on the basis of dimorphism in breast feathering as shown by the figures in table 26. The females, being significantly less susceptible to blister formation, show a significantly higher percentage of breast feathering at 8 weeks of age.

TABLE 25.

Sex Difference in Susceptibility to Breast Blisters.

	1941		1942	
Sex	Normal	Blistered	Normal	Blistered
Male	216	20	142	25
Female	218	1	91	1
	X^2 = 14.82 P = less than .01		X^2 = 11.17 P = less than .01	

TABLE 26.

Sex Difference in Relation to Breast Feathering in 1940.

Sex	(No)	Mean % Feathering	Mean Difference	t value	P value
Male	(25)	48.00	9.46 ± 4.13	2.29	.01 - .02
Female	(65)	57.46			

(c) Maturity.

Warren (1925 a) stated that in most breeds of poultry early maturity is associated with "rapid" feathering, but that this is not a necessary association. Data obtained by Marble (1934) indicate that it is impossible to forecast the subsequent date of first egg by means of an examination of the primary feather development at 8 to 10 weeks of age.

In the present study the degree of maturity in the females was measured by two different methods. At 5 months of age the birds were classified into early, medium and late maturing (table 27) according to the development of their secondary sexual characters such as comb, wattles, spread of pelvic bones and laying condition. On the basis of this arbitrary classification the differences in maturity observed at 5 months of age were insignificant both in 1940 and 1941. However this method of determining degree of maturity cannot be considered very accurate.

A second and more accurate method of measuring maturity, in number of days from hatching to first egg, was also used. Again the differences observed between the early and late feathering females were not statistically significant in either of the two years (table 28). It is interesting to note that by both methods of measuring

TABLE 27.

Degree of Maturity in Females at 5 Months of Age.

	1940 Maturity			1941 Maturity		
Feathering	Early	Medium	Late	Early	Medium	Late
Early	88	69	31	23	68	17
Late	71	83	47	32	67	12
X^2 = 5.92 P = .05 - .10				X^2 = 2.28 P = .30 - .50		

TABLE 28.

Age in Days at First Egg

Year	Feathering (No)	Age	Difference	t value	P value
1940	Early (93)	168.6	5.1 ± 3.01	1.69	.05 - .10
	Late (86)	173.7			
1941	Early (68)	192.7	6.7 ± 3.87	1.74	.05 - .10
	Late (70)	186.0			

maturity, differences observed were in the same order as weight at 5 months (table 16). Thus the heavier group at 5 months was also earlier maturing regardless of the type of feathering. However, environmental conditions that produced significant but contradictory differences in weight at 5 months did not influence maturity to the same degree.

(f) Egg Production.

Martin (1929) obtained a distinct interrelationship between high fecundity and rapidity of feathering in Barred Plymouth Rocks, which, he suggested, is possibly physiological in nature. On the other hand Hays and Sanborn (1942), working with Rhode Island Reds, found no relationship between the sex-linked gene for rapid chick feathering and several important inherited characters affecting egg production.

In the present study of the female population, with early and late sex-linked feathering types of females mixed together in each pen, egg production records were kept for two consecutive seasons. Data were based on a slightly different length of time during each of the two seasons. In 1940 the period of production covered 417 days and in 1941 it included 395 days from date of hatching. As shown previously in table 28, there was some difference in degree of maturity between the early and late feathering females as measured by age in days at first egg. A correction was, therefore, made so that egg production, in each of the two years, covers the same number of production days for the early and late feathering females.

Results obtained (table 29) show that the sex-linked early feathering females laid more eggs than the late feathering birds but this difference is statistically significant only in 1941.

TABLE 29.

Egg Production

	To 417 Days of Age (248.4 Production days)		To 395 Days of Age (209 Production days)	
Feathering	No.	Production	No.	Production
Early	41	150.4	52	134.4
Late	29	142.0	46	122.1
Difference		8.4 ± 5.49		1.23 ± 4.56
t value		1.53		2.69
p value		.10 - .20		less than .01

(g) Egg Weight.

Egg weights for individual hens were obtained by averaging the weights of ten consecutive eggs taken at about ten months of age. The eggs from the 1940 and 1941 early feathering pullets were somewhat heavier than the eggs from the sex-linked late feathering birds (table 30) but the differences were not statistically significant.

TABLE 30.

Egg Weight and Egg Color.

	Egg Weight in Gms.		Egg Color.	
Feathering	1940 (No)	1941 (No)	1940	1941
Early	61.97 (41)	60.65 (52)	5.3	4.4
Late	60.64 (29)	59.32 (46)	5.3	4.4
Difference	1.33 ± .731	1.33 ± .794		
t value	1.82	1.67		
P value	.05 - .10	.05 - .10		

(h) Egg Color.

In conjunction with egg weight studies, each hen's eggs were scored for egg color since a dark brown shell is desirable in the Barred Plymouth Rocks. This was repeated for two seasons on the same population used in the analysis of egg production. A uniform color standard was selected and the following score was allotted to various shades of brown.

Very light brown	2	Medium to dark brown	7
Very light to light brown	3	Dark brown	8
Light brown	4	Dark to very dark brown	9
Light to medium brown	5	Very dark brown	10
Medium brown	6		

There was no difference in egg color between the early and late feathering groups (table 30).

(i) Mortality.

The records on mortality of hens in this study commenced at 5 months of age and covered a period of about 8 months. Results presented in table 31 are based on 1940 and 1941 progeny for the same period of time each year. The Chi-square test and per cent mortality both reveal a significantly higher death rate of the late feathering females than the sex-linked late feathering birds.

TABLE 31

Hen Mortality.

Feathering	Alive	Dead	% Dead	X^2	P value
Early	114	13	10.23	3.99	.02 - .05
Late	109	27	19.71		

SUMMARY.

1. The present study confirmed previous findings that early feathering in Barred Plymouth Rock chickens is governed by a single recessive sex-linked factor.

2. There appeared to be indications of incomplete dominance of the sex-linked late-feathering gene in some heterozygous males at one day of age. The late feathering nature of such individuals was revealed by the absence of tail feathers at two weeks of age.

3. The early feathering Barred Plymouth Rock chicks develop feathers at a slightly slower rate than the New Hampshire chicks as revealed by examination of day-old and two-week-old birds. This was likely due to the same somatic inhibiting effect described by Danforth (1929).

4. The presence of the autosomal retarded factor prevents the development of tails in two-week-old chicks and hence it interferes with the accurate classification at this age on the basis of the sex-linked feathering genes. The retarded factor may be eliminated from a pure early feathering strain by critical test matings of all breeding stock to known homozygous retarded individuals in order to reveal the presence of this recessive trait.

5. There was no significant difference in day-old chick weights between the two feathering types of females. On the other hand the homozygous early feathering males were significantly heavier than the homozygous late feathering, whereas the heterozygous day-old males were intermediate in weight between the two homozygous types.

6. At 8 weeks of age the sex-linked early feathering females showed a significantly higher percentage of breast, back and pectoral region feathering than the late feathering females. Similarly the difference in length of primary wing feathers, tail feathers and pectoral feathers, at 6 weeks of age, was significant in favor of the early feathering females. The difference in length of tail feathers between the two types was found sufficiently great to permit reasonably accurate classification at 5 to 8 weeks.

7. Exclusive of the sex-linked feathering genes, significant positive correlations were obtained at 8 weeks of age between body weight and the following factors: length of primary wing feathers; length of tail feathers, per cent. of pectoral feathering, per cent. of breast feathering, and per cent. of back feathering.

8. The early feathering females showed a higher growth rate to the broiler stage than the late feathering type. With regard to males both the homozygous early and the heterozygous late feathering were significantly heavier than the unrelated homozygous late feathering males at 8 weeks of age.

9. There was no significant difference in mortality up to 5 months of age between the two feathering types of females. On the other hand the ss males showed a significantly higher mortality than the SS birds, whereas the heterozygous (Ss) males were intermediate in mortality between the two homozygous types up to 5 months of age.

10. The early feathering pullets showed a significantly higher body weight at five months of age than the late feathering group in 1940, but this difference was significant in favor of the late feathering the following season. At ten months of age, however, body weight differences between the two feathering types of females were insignificant, indicating that environmental conditions were responsible for the contradictory results at five months. In case of males, differences in body weight at six months of age were insignificant.

11. The late feathering females showed higher quality of barring of the wing and tail feathers, but no such difference was observed in the barring of back feathers between the two feathering types of females.

12. There was no difference in meat type between the two groups of females.

13. A significant relationship was established between sex-linked early feathering, per cent of breast feathering at eight weeks and resistance to breast blisters in Barred Plymouth Rocks. Furthermore the males showed a much higher degree of susceptibility to breast blisters associated with a significantly lower per cent of breast feathering at eight weeks than the females.

14. There was no difference in degree of maturity between the early and late feathering females.

15. Egg production and egg weight appear to be in favor of the sex-linked early feathering birds, whereas the egg color score was the same for the two feathering types of females.

16. The late feathering mature females showed a higher rate of mortality than the early feathering group.

CONCLUSION.

Results obtained in the present study indicate that sex-linked early feathering is desirable in Barred Plymouth Rock chickens. It is associated with important economic characters such as more rapid rate of growth and of feathering to the broiler stage, greater resistance to breast blisters, increased egg production and egg weight, and lower mortality in cockerel chicks and in mature hens. Of the factors studied, inferior quality of barring of the wing and tail feathers is the only undesirable trait associated with early feathering, but many individuals were equal to the slow feathering birds in this character so that selection of breeding stock would control the defect.

It would be possible to purify a strain of Barred Plymouth Rocks for the sex-linked early-feathering factor by the use of homozygous early feathering males (ss) for two successive generations.

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