A STUDY OF VARIABILITY IN THE FEATHERING OF RHODE ISLAND RED CHICKENS

by

MOHAMMED HASSAN RADI

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THE PROBLEM

The comparatively few studies of recent years on the problem of growth and development of feathers of birds give but little attention to the variation existing in the rate of feathering. Much variation has been observed in feathering of closely related birds as well as of those which are remotely related. Some authors have attempted to explain such differences on the basis of physiological reactions while others have attributed them to inherent genetical factors. This preliminary investigation, however, is not intended to explore the causes which make one bird at a given age fully clothed with feathers, while the other is practically naked, but to study the degree of variability in the feathering of the different regions of the bird's body. A detailed study of the causes of these variations in the rate of feathering, from the standpoint of both physiology and genetics, is to be considered in a subsequent investigation.

The primary aim of this thesis is to disclose any correlation which exists between the order of appearance of feathers growing on the different regions of the body as well as the influence of such factors as body weight, sex, and age.

REVIEW OF LITERATURE

The early works of the German Ornithologist, Nitzsch (1866), clearly demonstrate that the distribution of the plumage of birds is in limited tracts. These tracts are of definitive form and extent in regard to the area which they cover, a fact which enabled Nitzsch to classify the birds into groups on the basis of the characteristic appearance of their feather tracts. From his work on both domesticated and wild birds, Nitzsch distinguished the following feather tracts: dorsal tract (back), humeral tract (shoulder), femoral tract (thigh), inferior tract (belly), inferior tract (in few birds), head tract (head), alar tracts (wing coverts), crural tracts (leg), and caudal tracts (tail).

Pycraft (1900) cited the work of Nitzsch on feather tracts and added that the reason for the restriction of these tracts to certain areas of the body is to give greater freedom of movement to the limbs. He further stated that the number of feathers, or rather the size of the tracts, bears some sort of relation to the amount of specialization which the bird has undergone generally, and to the particular mode of life which the bird follows. As an example he refers to the crow as the most scantily clothed of birds, the tracts being very narrow, and the spaces in between very wide, whereas in the case of the ostrich the feather

tracts are of such great breadth as to make it difficult to find the bare spaces which normally separate one tract from the other.

Some genetic factors are known to affect the distribution of feather tracts. In a study of feathering of the hackleless fowl (naked neck), Greenwood (1927) reported that the examination of hackleless birds revealed that not only the dorsal region of the neck is affected by being naked but also a deviation from normal feathering was observed as well in the ventral regions of the neck and breast. In addition, he found that all feather tracts of the hackleless fowl are lacking the down and semi-plumes found in the tracts of the normal fowl. Greenwood concluded that the hackleless condition is the result of the failure of the feather follicles to develop in certain well-defined areas of the body due to genetic pecularity.

Landauer and Dunn (1930) who conducted an extensive study on the feather growth of the Silver Spangled fowl, reported that on the average 6 to 8 weeks were needed for a feather to make complete growth. They also found no indication of the existence of sexual differences in the growth rate of the feathers which they studied. On the other hand, they demonstrated the existence of a sexual difference with regard to the regenerative activity following removal be-

tween the feather follicles of certain regions of the body. The average time for regeneration of breast feathers was found to be 62.35 days in the male and 105.37 in the female. Similar differences were also found to exist in the case of both throat and pelvic wing (thigh) feathers.

Martin (1929), working with Barred Plymouth Rocks, concluded that the chicks of this breed feather dimorphitically with respect to rate, the males feathering more slowly. He also observed that the rate of development of feathers over the back is closely related to rate of growth, the heavier chicks feathering more rapidly. These results are in agreement with the findings of Gericke and Platt (1932) who, working on the influence of high and low protein level rations on feathering in Barred Plymouth Rocks, reported a positive correlation coefficient of 0.8120 $\pm$ .0109 between body weight and feather development at 8 weeks of age.

Axelsson (1932) states that analysis of data he obtained on the study of feathering in Rhode Island Reds and other breeds showed that the correlation between rate of feathering and rate of growth seems to be of a general physiological nature. He concluded that the differences in rate of feathering and rate of growth may be regarded as hereditary independently of each other.

Danforth (1929) observed that there is a considerable

difference in the time at which feathers first appear in young chicks, and also in the rate at which feathers grow after having made their appearance. He further stated that these differences tend to be associated with breeds. Lillie (1932) pointed out that Juhn and her co-workers have shown that different feather tracts of the Brown Leghorn fowl have inherently different growth rates.

Juhn (1931), working with Brown Leghorns, stated that the feathers in the posterior breast show the most rapid growth; next in order is the growth rate in the anterior breast, while the back and the saddle show relatively low growth rate, which is somewhat more rapid posteriorly than anteriorly.

Lillie and Juhn (1932) who made a study of the physiology of feather development in Brown Leghorns noted that different feather tracts have different rates of growth. They also noted that similar differences in rate of feather growth exist among the feathers of the same tract. Considering each individual feather, they furthermore reported that feathers in general exhibit bilateral asymmetry due to unequal rates of growth on the two sides of the feather. This condition was so pronounced to lead them to conclude that the two sides of the feather may behave entirely independently.

STOCK USED

The Rhode Island Red fowl, a chicken extensively used on American farms, has been selected for this study. Before attempting to locate those factors which are most influential in the development and growth of feathers, the extent to which the feathers vary under normal conditions must first be established and its significance determined.

Approximately 1,200 pedigreed birds from the Kansas Experiment Station flock have been raised for this purpose. They were kept under close observation from the time they were hatched until they became 8 weeks old. The data that were collected during this time served as a basis for this study.

This investigation was limited to the first 8 weeks of the bird's life since it is at this age that broilers of the Rhode Island Red breed are first marketable. The birds which are not well feathered when 8 weeks old are usually rejected or sold for a low price. In either case the broiler producer suffers a great economic loss, and in order that this study might be of some practical value the broiler age is the one at which the feathering was classified. It might be further stated that if the poultryman chooses to keep his Rhode Island Red broilers beyond 8 weeks

of age they may ultimately become fully feathered.

Compared with Leghorns or other Mediterranean breeds the Rhode Island Red fowl is a slow feathering bird. Leghorn birds usually feather out to the extent of covering the whole body before they reach the sixth week of age. Rhode Island Reds raised under the same conditions are commonly much slower in feathering and when they reach the broiler size a large percentage of them still have inferior feathering quality.

Prior to taking up this study, Warren (1925) had demonstrated that the difference in the rate of feathering between the so-called light and heavy breeds of the domestic fowl is due to a sex-linked factor. On the basis of this fact he was able to establish a strain of Rhode Island Reds which has the characteristic early feathering commonly found in the Leghorn breed, to which he has given the name early-feathering.

This early-feathering Rhode Island Red strain is distinctly different from the ordinary late-feathering Reds, as far as feather growth and development is concerned. Upon reaching the eighth week, the early-feathered Reds are usually fully clothed with long feathers where the late-feathered birds would have short, immature feathers on the various areas of the body.

In this investigation I have used both early- and late-feathering Reds as experimental stock. The results obtained on both in the various phases of study are discussed under the appropriate headings.

METHODS

Feather Tracts

For the purpose of this study ten feather tracts have been recognized. As previously stated each of these tracts covers a certain portion of the body. They also show a striking difference in manner of feathering one from the other. The wing feathers were not considered among these ten tracts. This was due to the fact that wing feathers are subject to definite hereditary growth factors which, according to Warren (1925) vary to a considerable extent among the different breeds of poultry. Wing feather development, however, was used as a means of predicting the future feathering condition of birds as will be discussed elsewhere in this thesis.

The name given to the tract has been derived from that portion of the body which the tract covers, thus making the name indicative of its location.

(1) The head tract includes all the feathers which cover the head. It extends as far posteriorly as the junc-

ture of attachment with the neck or at the place where the vertebral column joins the skull.

(2) The neck tract includes the feather covering of the entire neck region but the grade given was determined primarily by the feathered condition of the dorsal surface.

(3) The back tract covers the whole dorsal surface of the body extending between the neck anteriorly and the tail posteriorly.

(4) The tail tract includes the feathers growing on the most posterior portion of the vertebral column, the pygostyle (rump).

(5) The breast tract is composed of two parts which extend on both sides of the body parallel to the ribs and join each other anterior to the crop.

(6) The thigh tract is composed of the feathers arising on that area of the skin located opposite the femur bone.

(7) The belly tract is located on the ventral surface of the body on both sides of the sternum. It is comparatively narrow and has a few short feathers.

(8) The leg tract consists of the feathers growing on the tibial and fibular portions of the leg.

(9) The shoulder tract, including the feathers growing on the skin across from the humeral bone of the wing. The feathers are comparatively long.

(10) The web tract consists of those feathers growing on the web of the wings. They are comparatively short feathers.

The location of these tracts is shown on Plates I and II.

System of Grading

The differentiation among the birds used in this study was wholly based on the condition of feather development at the end of the eighth week. In order to obtain a somewhat uniform quantitative determination of the degree of feathering at this age, an arbitrary scoring system was devised. In estimating the feathering of a bird by this system, each of the ten feather tracts considered in this study was individually graded. A grade of three points was assigned to each of these tracts. In order that a tract might receive the perfect score of three points, the feathers growing upon this tract must be sufficiently long and abundant so as to completely cover the whole area of the tract. A tract with feathers although abundant but not quite long enough to exhibit a uniform surface was cut one point. In the same manner a tract was cut two points if the feathers were sparsely scattered over the area of the tract showing spaces free from feathers. On the other hand, a

PLATE I

Explanation of Plate I

Location of feather tracts -- dorsal view

bk - back

shd - shoulder

wb - web

th - thigh

Plate 1

PLATE II

Explanation of Plate II

Location of feather tracts -- lateral view

lg - leg

tl - tail

br - breast

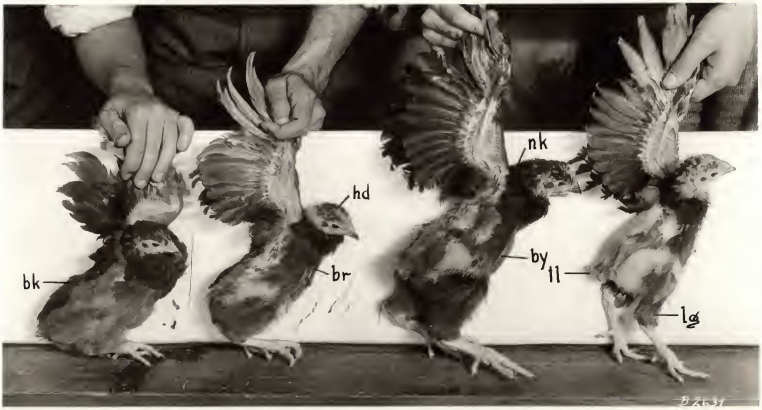
by - belly

nk - neck

bk - back

hd - head

Plate 2



tract upon which no feathers have appeared and with the down still persisting was given a score of zero. Thus a bird with well developed feathers on all of its ten tracts may make a total grade of thirty points.

All the birds which were used in this study were segregated as to sex and the sex record was incorporated into our data. In many cases, however, the sex of the birds was not distinguishable at the termination of the experimental period which was limited to 8 weeks. In these instances the birds were kept until the sex characters had sufficiently developed to enable positive sex determination.

EXPERIMENTAL

Order of Appearance of Feather Tracts

The time at which the feathers begin to appear on the surface of the skin differs considerably, according to the tract. It has been observed during this investigation that the feathers of some tracts make their first appearance during the first week following hatching while others remain in the downy condition as late as the eighth week or even later. In general, the appearance of the feathers is a gradual process which involves the whole tract system in an overlapping manner.

It is of interest to note that the appearance of the

feathers of the same tract also differs as to priority. The feathers located at the caudal end of the tract are usually the ones which appear first and also the ones which attain the greatest size.

A systematic study of the order of appearance of feather tracts was carried on as a part of this investigation. The birds devoted to this study were examined at weekly intervals from the time of hatching until the end of the eighth week. All the areas of the ten tracts were carefully examined at weekly intervals and the appearance of the feathers was recorded on individual cards. The data obtained on 48 Rhode Island Reds are shown in Table 1. This table shows the age distribution of the individual birds at the time of appearance of each tract.

The data on age at appearance of feather tracts as summarized in Table 1 show that the first tract to appear in the ordinary slow-feathered Rhode Island Reds is the shoulder. This is followed by the thigh, breast, neck, leg, tail, back, head, and belly tracts in succession. The web tract is the last to appear and the feathers of this tract do not ordinarily appear until the close of the fifth week following hatching. The data in this table also show that the maximum period elapsing from the day of hatching until all the tracts have appeared does not exceed 8 weeks. By the end of the eighth week all the tracts of the 48 birds

Table 1. Order of appearance of feather tracts in Rhode Island Reds

Tract	Distribution of birds on basis of age in weeks at time of appearance of tract															
	Males								Females							
	1 wk	2 wks	3 wks	4 wks	5 wks	6 wks	7 wks	8 wks	1 wk	2 wks	3 wks	4 wks	5 wks	6 wks	7 wks	8 wks
Shoulder	3	8	9	3	1				4	19	1					
Thigh			15	8	2					3	20	1				
Breast			17	5	3					4	11	1				
Neck			1	10	9	4		1			3	17	4			
Leg				17	4	3					4	18	2			
Tail				3	14	4	1	1			2	15	7			
Back				2	11	7	3	1			2	11	10	1		
Head				4	11	7	3				1	10	9	4		
Belly					9	9	3	1			1	5	15	3		
Web				1	7	11	3	2				6	16	2		

included in Table 1 had made their appearance.

For comparison with the Rhode Island Reds a study on the appearance of feather tracts in the White Leghorn was also undertaken. In this study two distinctly different strains of the Leghorn breed were used, one was the normal early-feathered while the other was a strain of White Leghorns in which the late feathering trait had been fixed. These two strains had been bred for a number of years on the college poultry farm and they are known to breed true for their respective characteristic feathering. Furthermore, the early-feathered Leghorn strain is believed to be comparable with the early-feathered Rhode Island Red strain as to the genetic factors controlling feathering. A similar parallelism is believed to exist between the late-feathering Leghorns and the normal late-feathering Rhode Island Reds.

The results obtained from observations on these two strains are shown in Table 2. It is evident from the data presented in this table that the two Leghorn strains differ widely as to the time at which their feather tracts appear and that in the female the appearance of a tract is somewhat accelerated when compared with the male.

Table 2 shows that the order of appearance of feather tracts in the two strains of White Leghorns, early- and late-feathered, respectively, differ somewhat from that found in the Rhode Island Reds. In the normal White Leghorns

Table 2. Order of appearance of feather tracts in White Leghorns

Tract	Strain	Distribution of birds on basis of age in weeks at time of appearance of tract											
		Males						Females					
		1 wk	2 wks	3 wks	4 wks	5 wks	6 wks	1 wk	2 wks	3 wks	4 wks	5 wks	6 wks
Tail	Early	18						11					
	Late		2	1	12	2		1	5	5	4		
Shoulder	Early	18						10	1				
	Late		5	5	4	3		2	8	4	1		
Thigh	Early		16	2				1	9	1			
	Late		1	12	4				2	11	2		
Breast	Early		16	2				1	9	1			
	Late		1	12	4				3	11	1		
Neck	Early		2	15	1					11			
	Late			1	16					2	12		
Back	Early		2	13	3					9	2		
	Late			2	6	6	3			4	10	1	
Web	Early		1	13	4					9	2		
	Late				4	9	4			1	10	4	
Leg	Early			3	14	1				1	10		
	Late				15	2				2	12	1	
Belly	Early			1	15	2					10	1	
	Late				7	9	1				14	1	
Head	Early			1	9	8					8	3	
	Late				4	13					9	6	

(early feathering) the first tract to appear is the tail followed by the shoulder, thigh, breast, neck, back, web, leg, belly, and head in succession. The feathers of the head tract make their first appearance during the third week following hatching.

The time at which the tail and shoulder tracts appear seems to be a dependable basis for estimating the future feathering of the bird. The appearance of these two tracts during the first week is indicative of the sex-linked early feathering constitution while their delay beyond this time is evidence for the late feathering tendency. A glance at Table 2 reveals this to be the case. The 29 early-feathered birds included in Table 2 all had tails which appeared during the first week. The same is also true in the case of the shoulder of these 29 birds, with the exception of one bird. In the case of the late-feathered Leghorns, however, the appearance of these two tracts does not begin until the close of the second week.

It may also be concluded from Table 2 that the maximum period for appearing of all the tracts in the White Leghorn is 6 weeks, as compared with 8 weeks in the Rhode Island Reds.

A comparison between the time of appearance of feather tracts in the late-feathered Rhode Island Reds and the late-feathered Leghorns as indicated in Tables 1 and 2 reveals

the fact that the two strains differ. The feathers of the late-feathered Leghorns appear somewhat earlier than those of the late-feathered Rhode Island Reds. This difference in the time of appearance ranges from 1 week in some tracts like the thigh and the breast to 2 weeks as in the case of the tail tract.

The shoulder tract is the only tract which appears earlier in the Rhode Island Reds than in the Leghorns. This exception applies to the Rhode Island Red males only. In the females of both Rhode Island Reds and Leghorns this tract appears at about the same time.

Variability of Feathering in Sexes

Sexual dimorphism in the feathering of the Rhode Island Red fowl is of a striking nature. My observations on several hundred birds clearly show that the female sex, as a rule, feathers out earlier than the male. In the females the definitive feathers usually replace the down 1 or 2 weeks earlier than in the male. The eruption of feather follicles, or the appearance of the feathers upon the surface of the skin, was on the average, 1 week earlier in the female than in the male. The data presented in Table 1 indicate that this condition applies to all feather tracts of the Rhode Island Reds that have been considered in this study.

The back tract is the one which shows the most noticeable difference. In the majority of cases males have had poor feather growth over the back. The appearance of the feathers of this tract as well as their growth is of much lower rate in the male than in the female. In many instances I have found male birds which were fully clothed with feathers all over the body except on the back which was either sparsely covered with poorly-developed feathers or carrying only the chick down. In very few cases, however, was such a condition found to exist among females.

The sexual dimorphism was much more evidenced in case of the late- than in the early-feathered strain. The sexes of this latter strain did not exhibit any pronounced difference in feathering at the 8 week age. This might be attributed to the specific hereditary factors which accelerate the growth to where the two sexes come to attain a perfect degree of feathering upon reaching the eighth week. The sexes of the early-feathered strain do exhibit some difference in feathering in favor of the female sex prior to reaching the eighth week but this difference gradually disappears as the age progresses beyond the sixth or seventh week.

The degree of variability in feathering of the various tracts is usually higher in the male than in the female. The one exception is the back tract in which the females

show a higher degree of variability. This is evident from the data presented in Table 4. This table shows that while the majority of the females rank in the two top classes, indicating fair degree of uniformity in feathering of the same tract, the males are shown to be distributed all over the scale, an indication of the existence of a wide dissimilarity in the manner of feathering among them, thus resulting in a higher coefficient of variability.

Relation of Body Weight to Feathering

The influence of body weight upon the rate of feathering at 8 weeks was not great. The coefficient of correlation between the two variables, weight and grade of feathering, was found to be 0.1948 $\pm$ .0139 and 0.0550 $\pm$ .0161 in 305 males and 297 females, respectively. This coefficient is significant in both sexes as judged from the probable error. On the other hand, the value of the correlation coefficient itself was too low to be of any practical importance.

The analysis of data obtained from a similar study that was conducted by the Department of Poultry Husbandry of this institution during the year 1933, gave somewhat higher coefficients than those which I reported. According to these data, the coefficient of correlation between body weight and feathering score at 8 weeks was found to be 0.2398 $\pm$.0359

in 312 males and 0.3833 $\pm$ .0336 in 292 females. Although these coefficients are high enough to indicate some association between these two factors, the degree of association is too low to have much practical value.

Variability in Feather Growth within the Tract

There is a considerable amount of variation among the feathers growing on any of the above mentioned tracts. Some of the tracts show a striking variation in the length of their feathers, while in others such differences may easily escape notice unless the feathers are carefully examined.

The feathers of the thigh tract are perhaps the most variable ones being quite short anteriorly with progressive lengthening as the tract extends posteriorly. The feathers of the posterior portion of the tract are twice as long as the ones on the anterior portion. Such an arrangement of feathers also exists on the head, neck, back, breast, and shoulder tracts as shown in Table 3. The head and the belly tracts, although agreeing with the general feather arrangement of the other tracts, show less regional variation.

The feathers of the leg and the web tracts exhibit a different arrangement from that found in the rest of the tracts. In these two tracts the longer feathers are located in the proximal portion while the shorter ones are found in the distal portion of the tract.

Table 3. Comparison of mean length (millimeters) of feathers from different regions of the tracts

Tract	Males		Females	
	Anterior feathers	Posterior feathers	Anterior feathers	Posterior feathers
Head	10.1	17.4	12.4	18.5
Neck	24.2	35.6	27.1	38.3
Back	15.6	27.5	35.7	44.6
Breast	41.6	58.0	35.0	65.1
Belly	18.2	19.7	20.0	28.5
Thigh	29.9	62.0	47.5	63.1
Shoulder	29.9	57.0	39.7	60.2
	Distal	Proximal	Distal	Proximal
Leg	22.5	32.3	19.3	28.3
Web	16.2	21.2	15.2	20.0

Because of such wide variability among the feathers of the same tract it has been necessary in comparing the growth to confine our observations to a mid-section of the tract, thus avoiding the influence of regional variability.

It is of interest to note that the longest feathers of the tract, especially in the breast and shoulder tracts, are those which appear first as definitive feathers replacing the down. This fact is considered in detail elsewhere in

this thesis.

Variability in Feathering Among the Different Tracts

The various feather tracts differ widely in their manner of feathering. The extent of the tract area; the length of feathers and their structure, whether soft or coarse; the density and sparseness of growth; the closeness of feathers to the surface of the skin are all common features of variability among tracts.

The feathers of the breast and thigh tracts are usually soft, flowing, and somewhat long, while those of the head and web tracts are comparatively short and lay close to the surface of the skin.

It is evident from the data presented in Table 4 that there exists a considerable difference in manner of feathering of the various tracts. The back tract in the male is less variable than it is in the female. This situation was due to the fact that the majority of males had been classified as poorly feathered on the back and were thus included in the four lower classes as shown in Table 4. The females, however, exhibited varying degrees of back feathering ranging between the top and the bottom classes of the table and thus showed a relatively high coefficient of variability. Those tracts showing the high coefficients of variability are the ones most influential in determining the

Table 4. Variability in degree of feathering of the various tracts at the 8-week age

Class	Distribution with respect to feathering grade and coefficient of variability													
	Back		Neck		Shoulder		Breast		Belly		Thigh	
Grade at 8 weeks	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
2.6-3.0		14	7	47	11	99	2	32		1	4	35
2.1-2.5												
1.6-2.0	22	97	138	141	80	92	77	144		5	81	147
1.1-1.5	1											
0.6-1.0	85	64	33	10	74	8	70	21	4	47	59	7
0.0-0.5	77	25	7	2	20	1	36	3	181	147	41	16
Total	185	200	185	200	185	200	185	200	185	200	185	200
Cof. Var.	22.00	52.74	33.03	31.59	53.73	26.75	57.90	30.60	76.35	35.25	56.32	25.96

total feathering score of the bird.

From the foregoing discussion it is evident that feather growth differs a great deal from one tract to another. In order to bring out this fact more clearly a correlation study between the 8-week feathering grade and the grade of the individual tracts was made.

The linear correlation method was not found applicable to our data. The principle underlying calculation of the coefficient of correlation by the linear method is based on the assumption that both of the correlated traits are normally distributed. In other words, each trait should exhibit a fairly normal curve when placed in a frequency table.

In the case of our data, however, an extremely skewed distribution was obtained, more so in the case of females than in males. This situation was the result of a large number of female birds making a high feathering score at the 8-week age, thus resulting in approximately 40 per cent of the females falling into the highest class of the distribution. Males also showed a skewed distribution curve, though not so extreme as in the case of the females.

The tetrachoric method of correlation was found to be more fitted to meet this situation than does the linear method. The tetrachoric method is also called the four-fold method. It was first described by Karl Pearson (1902), and

it derives its name from the fact that the frequency table consists only of four cells. More recently, Everitt (1910) and Kelley (1924) have described methods of obtaining the tetrachoric coefficient of correlation. Kelley's method was applied to my data to obtain the coefficient of correlation between the total score of birds at 8 weeks and the score of some of the important feather tracts from the standpoint of covering the bird. These coefficients are given in Table 5.

Table 5. Coefficients of correlation between the score of various feather tracts and the total score secured from consideration of all tracts

Tract	Males	Females
Back	0.5628 ± .0622	0.4533 ± .0659
Neck	0.3504 ± .1036	0.1298 ± .0680
Thigh	0.1139 ± .0646	0.0867 ± .0993
Shoulder	0.1097 ± .0722	0.0630 ± .0222
Back, neck, and shoulder	0.4682 ± .0740	0.1337 ± .0620

From this table it may be inferred that the correlation coefficient between the feathering score at 8 weeks of age and the score of the back tract is a reliable measure for estimating the feathering condition of either sex. This coefficient is somewhat higher in the male than in the fe-

male. This may be accounted for on the basis that females in general are of less varied feathering than the males and, therefore, a larger number of them are classed as having better feathering, thus outweighing, to some extent, the number of birds in the less better feathered classes resulting in a reduced coefficient being obtained.

The coefficient of correlation between the neck tract and the 8-week feathering score is smaller than that obtained from the back tract. In the male it is only about three times as large as its probable error, while in the female it is not quite twice so large. These values are of questionable significance indicating that this tract is not of great importance in determining the feathering condition at the 8-week age.

The coefficients obtained from the thigh and the shoulder tracts of either sex are of no significance as judged from their comparatively larger probable errors, hence, these coefficients could not be used as reliable measures of estimate.

The back, neck, and shoulder tracts, taken as one group, give much higher correlation coefficient in the male than in the female, but show no advantage over the back alone.

Relation of Time of Feather Appearance to the Degree of Feather Development

As a rule the feathers which appear first on the tract are the longest and the largest ones of that particular tract. This rule seems to hold true in case of the feathers of the individual tracts, but in comparing the time of appearance of the different tracts with the degree of development attained in their feathers we find an entirely different situation. The tract which appears first is not necessarily the one which makes the maximum development. I have noticed in particular that although the feathers of the back may precede those of the neck or head in making their appearance, upon reaching the eighth week the neck frequently has the higher score. Such a condition is an indication of the complicated phenomena by which feather development is controlled. It, therefore, seems plausible to assume that different feather tracts are not subject to control by the same factors, or that they react in various ways to the controlling factors.

Relation of Degree of Feathering at Earlier Ages to the 8-week Feathering Score

Development of wing feathers of day-old chicks and the 8-week feathering score. One of the problems considered

during the course of this investigation was determining the relationship between the growth rate of the primary wing feathers and the feathering condition of the bird at 8 weeks. The primary wing feathers are the first definitive feathers to appear on the chick of the domestic fowl. As a rule, these feathers appear before the chick hatches. The length of the primary wing feathers at the time of hatching varies greatly. For example, the chicks of the Mediterranean breeds have much longer primaries than those of either American or English breeds. This difference in the rate of growth of the wing primaries has been demonstrated to be due to certain hereditary factors. The early-feathered strain of Rhode Island Reds, which was used possesses those factors which accelerate the growth of wing primaries at hatching. The chicks of this strain exhibit a condition quite similar to that found in the Mediterranean breeds. Rhode Island Red chicks show wing primaries upon hatching varying some in degrees of growth but never the extreme wing feather growth which characterizes the chicks of the early-feathered strain.

All the chicks that were hatched during the season of 1934 were examined on the day of hatching to determine the relative length exhibited by the wing primaries. These chicks were classified into three groups, according to the length of their primary feathers. Those which had primaries

approximately three-fourths an inch in length comprised one group. The second group was made up of those chicks having primaries having a length of approximately one-half inch. The third group consisted of chicks with primaries about one-third of an inch in length. After the chicks were examined on the day of hatching a mark was placed on the individual data card of each chick to designate the group to which it belonged. Upon reaching the eighth week of age, the degree of feather growth was determined according to the scoring scale previously described. It is of interest to note that the birds, with only three exceptions, that were placed in the first group, or those which had long primary feathers at the time of hatching, were found to belong to the early-feathered strain. This result indicates that the wing primaries of baby chicks of this strain are of distinct type that could not be mistaken for other types. The birds of the late-feathered strain comprised the two groups of medium and short wing primaries. The mean 8-week feathering score of the birds of each of the two groups, medium and short primaries, respectively, was calculated. The result of this classification is presented in Table 6.

Table 6. Relation of length of wing primaries in day-old chicks to the degree of feathering at 8 weeks of age

	Day-old chicks with medium length primaries		Day-old chicks with short primaries	
	Number of birds	8-week mean feathering score	Number of birds	8-week mean feathering score
Females	220	27.55	77	27.03
Males	210	23.82	95	22.18

From the results summarized in Table 6 it may be inferred that the length of primary wing feathers at hatching does not seem to bear any relation to the 8-week feathering condition. The birds which were designated as having medium primaries as baby chicks showed no appreciable difference in the degree of feathering at 8 weeks of age from those which were classified as having medium primaries. The lack of difference between these two groups of birds may be due to the fact that variation in wing length in day-old chicks may be due to the time elapsing since hatching rather than the inherent feathering tendencies of the chick. The chicks which emerged from the shell first are most likely the ones which were classed as having longer primaries, while those which hatched late are probably the ones which had short primaries and, therefore, were designated as such. At any

rate my data indicate that this measure of variability is not to be relied upon for our purposes.

Development of wing feathers of 13-day old chicks and the 8-week feathering score. Another point of interest that was studied during the course of this investigation is the relationship between the length of wing feathers at 13 days of the post-embryonic life and the 8-week feathering score. In this experiment the birds were examined on the thirteenth day of age and the length of their wing feathers was noted in comparison with the length of the body. The length of the wing feathers at this stage of development varied a great deal from one bird to another. Some birds had wings, the tip of which when folded reached approximately half of the length of their bodies, while in others these feathers were as long as seven-eighths of the body. The birds were thus classified into four groups, according to the length of their wings. These groups were designated as 1/2, 2/3, 3/4, and 7/8, in comparison with body length. At the termination of the experimental period of 8 weeks and after the birds had been graded according to the scoring scale previously mentioned, the birds were then classified into these four different groups and the mean 8-week feathering score of each of these four groups was determined.

The results of the classification of 305 males and 297 females are summarized in Table 7.

Table 7. Relation of length of primaries in 13-day-old chicks to the degree of feathering at 8 weeks of age

	The length of wing at 12 days as compared with body length			
	1/2	2/3	3/4	7/8
Mean 8-week feathering score of:				
Females	26.38	27.66	28.27	29.00
Males	22.45	23.93	26.85	

The data in this table show that the longer the wing in relation to body length at 13 days of age the better the feathering at 8 weeks and vice versa. This fact might be utilized as an index for evaluating the future feathering of the bird. As the chicks increase in age, however, the reliability of this test decreases on account of the difficulty encountered in accurately estimating the relationship between the lengths of the two variables, wing primaries and body.

Relationship between 3-week and 8-week feathering. One of the phases of this investigation has been the study of the relationship between feathering at different ages. The birds were all examined at 3 and at 8 weeks of age. On both occasions the birds were graded, as to the degree of feather development according to the scoring system pre-

viously described. Two hundred fifty-four males and 272 females were included in this study. The analysis of the data obtained proves the existence of a close relationship between the degree of feathering at 3 weeks and at 8 weeks of age. In other words, the birds which scored high at the age of 3 weeks were also among the ones which made a high feathering score at the close of the eighth week. The coefficient of correlation between these two variables, 3-week and 8-week feathering scores, respectively, was found to be 0.5896 $\pm$ .0276 in the case of the males and 0.5840 $\pm$ .0269 in the case of the females.

DISCUSSION

The fact that female birds usually have better feathering than the males might be attributed to some physiological difference between the two sexes, hormonic or otherwise.

The coefficient of correlation between body weight and the 8-week feathering condition obtained in this study seems to be quite low when compared with that reported by Gericke and Platt (1932). They reported a coefficient of 0.8120 $\pm$ .0109 while our highest value was 0.3833 $\pm$ .0336. This difference in the results may be accounted for by the fact that Gericke and his co-worker fed their birds on rations of different protein levels, some of which were high while others were deficient in protein content. In my work,

however, I used only one ration containing a moderate amount of protein. Their results indicate that high protein rations tend to stimulate body growth which in turn influences feather growth, while low protein rations retard both body and feather growth. The difference in the composition of the rations used in the two experiments as regards protein content, seems to be the factor responsible for the difference in the values of the correlation coefficient obtained.

Among the feathers of the same tract; those feathers which appear first are, as a rule, the ones which reach the maximum length. This rule, however, does not hold when applied to the feathers of the different tracts with respect to either length or degree of coverage. A tract might precede another in the time of appearance, but the one which appears first is not necessarily the one which makes the maximum growth at the close of the eighth week. The back and the tail feathers usually appear earlier than do those of the belly or the web, but upon reaching the eighth week the two tracts which appear first seldom make as high score as that made by the ones which appear later. This condition indicates that highly refined and specified control is exercised over the feathers of the various regions of the body. The nature of this control, however, is not known.

The correlation coefficients between the 8-week feather-

ing grade and the grade of the individual feather tracts made at the same period was higher in the male than in the female. This has been found to be true in all the cases reported in this study. The reason for this was probably due to the females feathering earlier than the males and approaching a superior degree of feather growth by the end of the eighth week, the time at which the birds were graded. This would result in a much less variability in feathering among the females than among the males. Approximately one-half of the females used in this study were given the maximum feathering grade of 30 points when graded at the end of the eighth week. This tendency of a large portion of the females to make a perfect feathering score at the close of the experimental period of 8 weeks, had undoubtedly obscured some of the variations in the feathering of the tracts which might have existed before reaching the eighth week and, therefore, should account for the lower coefficients obtained in this sex.

As a rule, the feather tracts which contribute most to the coverage of the bird, or those with large areas and abundance of feather growth, appear earlier than the ones having smaller areas or short and scanty feathers. This priority in feather appearance might have its origin in the natural need of the body for covering which as might be expected, begins with the more exposed areas of the breast,

shoulder, and thighs, and provides later for the less important belly and web regions.

SUMMARY AND CONCLUSIONS

(1) Females feather out earlier and their feathers grow more rapidly than those of males.

(2) The feathers located at the posterior portion of the tract are longer than those located at the anterior portion. This feather arrangement has been found to be true in practically all tracts studied except in the leg and the web in which long feathers are located proximally and the shorter ones distally.

(3) The age at appearance of feathers in the various tracts is relatively regular. In the case of the Rhode Island Reds, the first tract to appear is the shoulder, followed by the thigh, breast, neck, leg, tail, back, head, belly, and web.

(4) The order of appearance of feather tracts in two strains of White Leghorns differs somewhat from that found in the Rhode Island Reds.

(5) In studies conducted in two successive years, the coefficient of correlation between body weight and feathering score at 8 weeks of age was of questionable significance.

(6) In the males the thigh shows the highest coefficient of variability, and is followed in order by the

breast, belly, shoulder, neck, and back. In the females the tracts have the following rank: back, thigh, neck, breast, shoulder, and belly.

(7) A positive and high correlation has been demonstrated to exist in both sexes between the total feathering score at 8 weeks of age and the score of the back.

(8) The degree of association between the individual scores of the neck, thigh, and shoulder and the total 8-week feathering score, as indicated by the coefficient of correlation has no practical significance.

(9) The length of the primary wing feathers as determined on the day of hatching seems to have no relation to feathering score made at the eighth week.

(10) A significant positive correlation exists between the length of the primary wing feathers at 13 days and the 8-week feathering score.

(11) The correlation coefficient between two feathering scores made at the third and the eighth week, was found to be positive and highly significant in both sexes.

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