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Relation of Juvenile Plumage to Growth and Sexual Maturity*

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THE process of plumage development in the domestic fowl was studied first by Rice, Nixon, and Rogers (1908). They found that the sequence of molts in the domestic fowl (using S. C. White Leghorns) corresponds very closely to the sequence of molts in young wild birds as previously reported by Dwight (1900). Rice stained the first feathers red and the second set black. They report that at eight weeks all the red feathers in the tail and wings had been molted, and at thirteen weeks, all the black feathers had been replaced by white ones. They did not observe further wing or tail molt until just before the birds reached maturity, when the pullets shed all their feathers and assumed mature plumage.

Lippincott (1920) observed on both American and Mediterranean breeds that the pelvic wing feather tract developed at about three weeks of age. He noted that this occurred at the same time or slightly preceding the development in the humeral or shoulder tract. Martin (1929) reported that in Barred Plymouth Rocks the heavier

chicks feathered more rapidly over the back than the smaller chicks. Dunn and Landauer (1930) and Warren and Gordon (1931) have studied very carefully the development of the juvenile plumage. Dunn and Landauer worked with Silver Spangled Hamburgs whereas Warren and Gordon studied S. C. White Leghorns. Both of these studies show that the chick from day old to maturity replaces its wing and tail feathers only once.

This study on plumage development and its various relationships was undertaken in December, 1930, when weekly observations were started on a group of one hundred and seventy-five day-old S. C. White Leghorn chicks. Each chick was examined for body feather development in the following seven feather tracts: neck, shoulder, dorsal, pelvic wing, thigh, pectoral, and sternal. The amount of plumage development in each feather tract was estimated and recorded by use of the figures 0 to 10 inclusive. For example, figure 0 was used when no feathers were in the process of growth, 5 when 50 percent were growing, and 10 when all feathers in one tract were being renewed. As a result, the maximum body molt value for the seven feather tracts at any particu-

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TABLE 1.—Average weekly weight and average body molt of *S. C. White Leghorns* from day old to twenty weeks of age

Age	Females (90 birds)			Males (73 birds)		
	Ave. wt. in grams	Rate of gain	Ave. body molt	Ave. wt. in grams	Rate of gain	Ave. body molt
0	31.40			31.31		
1	54.20	54.60	4.26	58.10	61.83	3.31
2	85.49	45.57	18.10	91.89	45.85	15.88
3	128.24	40.55	32.83	142.92	44.17	30.67
4	194.31	41.56	43.23	217.78	42.12	41.70
5	260.38	29.27	44.39	283.56	26.75	44.18
6	347.66	28.81	46.28	384.12	30.00	38.74
7	431.57	21.72	35.44	481.50	22.60	30.08
8	513.21	17.33	35.69	611.63	23.92	27.19
9	618.04	18.59	33.83	765.15	22.40	27.52
10	728.36	16.42	34.98	880.15	14.00	37.32
11	821.33	12.01	39.87	994.33	12.20	39.86
12	896.94	8.81	39.57	1118.84	11.80	38.38
13	964.87	7.30	30.88	1201.00	7.09	36.36
14	1065.51	9.92	23.03	1310.82	8.75	30.01
15	1130.13	5.89	20.90	1412.44	7.47	21.62
16	1183.88	4.65	16.51	1488.04	5.21	18.26
17	1224.57	3.38	12.88	1519.27	2.08	13.15
18	1283.50	4.70	8.58	1581.44	4.01	8.81
19	1383.72	7.53	7.58	1599.52	1.14	7.11
20	1446.24	4.41	6.31	1650.62	3.15	5.52

Rate of gain calculated according to the following formula suggested by Brody (1926): $K = \ln W^2 - \ln W^1$ in which K = average instantaneous relative rate

$\ln W^2$ = natural logarithm of the weight at the end of the period

$\ln W^1$ = natural logarithm of the weight at the beginning of the period.

lar week would be 70. Each primary feather was measured weekly and the number of secondary and tail feathers in the process of development indicated on the record sheet.

EXPERIMENTAL RESULTS

Body plumage.—Body feathers were showing on the shoulders at one week of age. Distinct feathers as long as one centimeter were observed in this section on many birds. At two weeks of age, all feather tracts except the sternal and thigh regions showed feather development. Slight development was observed on a few birds in these two regions. When the birds were three weeks of age, the weakest chick continued to be lacking in feather development on the sternal and thigh tracts. At four weeks of age, new feathers were being added (not replacement of old feathers dropped out) especially along the pelvic wing, pectoral and dorsal

tracts. Many of the shoulder feathers were full grown.

The following week, the quills of most of the feathers showed distinct hardening. At the sixth weekly observation, the females showed considerable molt in the neck, back, pelvic wing, and pectoral regions. No molt was evident in the males at this age. This gradual molt continued to show more distinctly in the females than in the males during the seventh and eighth weeks.

Table 1 shows the average weekly weight of 90 females and 73 males from hatching until twenty weeks of age. It likewise shows the average amount of body molt in progress each week. Two peaks of body molt are evident in both the males and females, both occurring at approximately the same time in the two sexes. The first peak in each sex was due to additional feather development rather than the renewal of old feathers. The

TABLE 2.—The stage to which the primary feathers developed in S. C. White Leghorn females from day old to sixteen weeks of age*

Primary feathers	1	2	3	4	5	6	7	8	9	10
Age										
1 week							41	49		
2 weeks								88	2	
3 weeks								1	88	1
4 weeks									16	74
5 weeks	58									32
6 weeks	47	42								1
7 weeks	3	71	16							
8 weeks		10	63	17						
9 weeks			15	64	11					
10 weeks				12	66	12				
11 weeks				1	14	74	1			
12 weeks					4	39	47			
13 weeks						10	76	4		
14 weeks						2	24	64		
15 weeks							8	72	10	
16 weeks							2	32	56	

* The figures in this table are the number of birds having reached the various stages of primary feather development. For example, at 6 weeks of age one bird was still growing the tenth primary feather, but had not started to drop any of the primaries. At the same age, 47 birds had dropped No. 1 primary and 42 birds had dropped both No. 1 and No. 2 primaries.

females showed a higher index of body molt during the period from the sixth to the ninth weeks than was exhibited by the males. The fact that the index value for body molt is seldom over one-half of the maximum value obtainable if all feathers in all sections were being renewed shows that these juvenile plumage changes are very gradual.

Wing and tail feathers.—Comparison of the development of the wing and tail feathers in the Silver Spangled Hamburgs studied by Dunn and Landauer (1930) with the S. C. White Leghorns used in this study points to the fact that the development in the S. C. White Leghorns is more rapid than in the Silver Spangled Hamburgs. Continued selection for early maturity in addition to natural breed differences probably are responsible for this more rapid development.

Tables 2 and 3 show clearly that following the original development of the ten chick primary feathers only one molt takes place prior to maturity. At the age of four weeks, the primary feather development of the females became more rapid than that of

the males. At the age of ten weeks, the females were one primary feather ahead of the males.

In the secondary division of the wing, nine feathers were visible at one week of age. The following week a new secondary had appeared on either side of the original nine feathers. These two new feathers proved to be the first and eleventh when counting from the axial feather toward the body. At three weeks of age, the full fourteen secondaries were showing on some of the birds. The first evidence of dropping of the secondaries appeared at the age of seven weeks when the second and occasionally the third secondary had been dropped. The order of molt of the secondary feathers is slightly different from that reported by the author (1930) for laying hens. In case of laying hens, the four or five feathers nearest the body were the first secondaries to drop. The molt then shifts to the second secondary and the feathers drop in regular order proceeding from the second secondary to the ninth secondary. The first secondary and the axial feather drop last. With the developing pullet or cockerel the secondary

TABLE 3.—*The stage to which the primary feathers developed in S. C. White Leghorn males from day old to sixteen weeks of age.**

Primary feathers	1	2	3	4	5	6	7	8	9	10
Age										
1 week							55	18		
2 weeks								72	1	
3 weeks								10	63	
4 weeks									36	37
5 weeks	28								1	44
6 weeks	61	9								3
7 weeks	14	58	1							
8 weeks		37	36							
9 weeks		3	45	25						
10 weeks			10	44	19					
11 weeks				14	54	4	1			
12 weeks				2	33	37	1			
13 weeks					5	55	12	1		
14 weeks					3	36	33	1		
15 weeks						6	57	10		
16 weeks						4	41	27	1	

* The figures in this table are the number of birds having reached the various stages of primary feather development. For example, at 7 weeks of age, 14 of the birds had dropped No. 1 primary, 58 had dropped the 1st and 2nd primaries and one bird had reached the stage where the 3rd primary feather had dropped

feather molt begins at the second secondary and progresses in regular order to the tenth secondary at which time the first secondary is dropped. The shorter feathers nearest the body drop out last. This order of molt in the juvenile bird is very similar to the order of development when the secondary feathers are first forming.

Effect of Molt Upon Growth Rate

The post-natal rate of growth of the domestic fowl has been observed and reported by many investigators. They are not in agreement regarding the presence of cycles of growth.

Table 1 reports the rate of gain in both the males and females. There appears to be no influence of the amount of body molt upon the rate of gain observed with either sex. The two peaks of molt are not accompanied by lower rates of gain. Comparison of the average weekly weights with the average body molt by weeks would suggest the absence of any group relationship between rate of growth and amount of molt. Study of the individuals by correlation analyses does point out certain individual relation-

ships which it is impossible to demonstrate by group averages.

Table 4 shows the correlation values obtained between body weight and body molt at various ages.

TABLE 4.—*Correlations between body molt completed at various ages and the body weight at the respective age*

Age	Females	Males
4 weeks	+ .565 ± .048	+ .635 ± .047
8 weeks	+ .398 ± .060	+ .726 ± .037
12 weeks	+ .484 ± .054	+ .589 ± .052
16 weeks	+ .440 ± .057	+ .610 ± .050
20 weeks	+ .308 ± .064	+ .518 ± .058

These correlations illustrate a distinct tendency for the heavier birds to show greater plumage development, especially in the males. The influence of body weight upon plumage development is strongest during the early weeks of the bird's life. Correlations between the actual body gain for any of the four week periods and the amount of body molt accomplished during the same periods point out the fact that this relationship is apparently very important during the

TABLE 5.—Average number of days to sexual maturity for birds attaining varying degrees of primary feather development at ten weeks of age

Year	Pen No.	Four primaries dropped		Five primaries dropped		Six primaries dropped	
		No. birds	Ave. days to maturity	No. birds	Ave. days to maturity	No. birds	Ave. days to maturity
1930-31		11	164.1±2.02	56	151.1±.93	12	151.8±1.53
1932	1	8	176.7	35	173.5	2	189.5
1932	2	6	192.5	23	183.0	6	177.5
1932	3	5	179.8	33	181.7	2	166.0
1932	4	6	183.7	33	189.1	4	177.0
1932	5	4	182.5	33	182.5	3	180.7
1932	6	2	171.0	24	190.7	5	171.8
1932	7	3	176.0	25	183.2	2	167.0
1932	8	3	186.7	33	177.8	3	177.7
Ave. of 1932 data		37	179.86±1.49	239	180.11±.79	27	175.74±1.93

first four weeks of the bird's life but less significant after four weeks of age.

Analyses of the relationship of days to sexual maturity with body molt show that birds which were observed to have the most intense molt in the body plumage did not mature either earlier or later than less intense molters. The correlation value obtained between the body molt to twenty weeks of age and days to maturity was $+ .030 \pm .071$. This lack of relationship is not surprising since most pullets have completed their body molt before the primary wing molt is completed. As a result, the time of sexual maturity is associated more closely with the primary feather development than with body plumage development.

Relationship of Primary Feather Development to Age at Sexual Maturity

In this group of pullets, 79 laid in the trapnest. In 1932, similar observations were made of the stage of primary feather development of Single Comb White Leghorn pullets in eight pens fed on varying levels of cod liver oil. Data on primary feather development were obtained at eight and ten weeks of age on 308 pullets. Since the average number of days to maturity were practically the same for the different groups at both eight and ten weeks, the data pre-

sented in Table 5 are for observations at 10 weeks of age only.

Analyses of the data in this table indicate that there is little possibility of forecasting the approximate date of first egg by an examination of the primary feathers at ten weeks of age. The birds showing the most advanced stage of primary feather development matured slightly earlier than the birds in either the least or medium advanced groups. In the group studied in 1930, the difference in number of days between the group which had dropped four primary feathers and the group which had dropped five primary feathers was 13.02 ± 2.22 days. This difference is statistically significant. The difference between the five- and six-primary feather groups was $.76 \pm 1.79$ days. In the 1932 data the differences were $.25 \pm 1.69$ days and 4.37 ± 2.08 days, respectively. With the exception of the difference between the four and five primary feather groups in 1930 these differences are not statistically significant.

Everyone familiar with culling laying birds has probably observed that a percentage of the flock are still carrying one or more chick feathers. The relationship of this sexual maturity has never been brought to the author's attention in any published report. In order to obtain information on

TABLE 6.—Average number of days to sexual maturity for hens carrying chick feathers through first year

No. chick feathers carried over		0		1		2		3	
Year	Pen No.	No. birds	Ave. days to maturity	No. birds	Ave. days to maturity	No. birds	Ave. days to maturity	No. birds	Ave. days to maturity
1930	1 & 2	23	177.2±1.59	58	157.9±1.08	10	149.0±1.17		
1930	12 & 13	21	174.5±1.54	40	161.7±1.61	17	152.6±2.13	3	143.0±1.27
1932	1	15	187.7	27	169.6	1	155.0		
1932	2	23	185.6	9	177.7	1	156.0		
1932	3	23	186.5	15	168.9	1	155.0		
1932	4	19	191.2	17	181.7	2	180.5		
1932	5	22	188.0	15	174.5	2	181.0		
1932	6	13	182.6	16	170.7	3	157.7		
1932	7	13	189.8	14	172.8				
1932	8	25	185.4	12	166.0	1	155.0		
Ave. 1932		153	186.4±.86	125	172.2±.89	11	164.1±2.52		

this point, examination was made of several pens of birds at the age of eight months. The results are shown in Table 6. There appears to be a definite relationship between the "carry over" of chick feathers and the age at which the pullet lays her first egg. The differences between the mean days to sexual maturity for the various groups of birds as shown in Table 6 are all statistically significant with the exception of the one- and two-chick-feather groups for 1932. In this instance, the value of D./P.E. is 3.03, or slightly below the point of statistical significance.

Since the age at sexual maturity is related to annual egg production as shown by many investigators it is helpful to have an additional key for the determination of date of first egg. Pigmentation is helpful in estimating the date of maturity provided the examination is made before the bird has bleached in the beak and before the vacation has occurred. The value of the chick feather "carry over" lies in the fact that if, due to management factors, the bird takes a vacation and passes through a partial molt the chick feathers are not dropped out. The

primary feathers nearest the axial feather are dropped in case of a vacation molt and a complete molt is necessary in order to destroy the evidence furnished by the chick feather "carry over."

SUMMARY

Analyses of data on 90 females and 73 males from day old until twenty weeks of age definitely indicate two peaks of body molt and one complete wing and tail feather molt following the original growth of these feathers. Significant changes in the rate of growth did not occur during these peaks of body plumage development. Significant positive correlations were found to exist in both sexes between the body weight at four, eight, twelve, sixteen, and twenty weeks of age and the amount of body molt completed at the respective age.

Analyses of data obtained on 79 pullets in 1930 and 308 pullets in 1932 (all S. C. White Leghorns) indicate that it is impossible to forecast the subsequent date of first egg by means of an examination of the primary feather development at eight or ten weeks of age. The data do show a definite

tendency for early maturing pullets to carry over one or more chick feathers throughout the first laying year.

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