AN ANALYSIS OF FACTORS AFFECTING AMOUNT OF FEATHER IN DOMESTIC FOWL, *Gallus domesticus*.

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By

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INTRODUCTION

Where a phase of research must be completed within a short period of time, it is necessary to select and plan a problem that will yield, if possible, definite results in this allotted period. Many such problems are undertaken by graduate students. Within a limited time the data must be collected, analyized, evaluated and appropriately discussed in such a manner that it will add something new to the already large and growing amount of information in a respective field. Such a problem is the present one.

Due to the tedious, laborious method required to count feathers, few actual counts have been made. As a result, there is a very limited amount of published data on the total number of feathers found on the several breeds and varieties of domesticated fowl. Resulting therefrom are a number of conflicting reports as to the total feather number found on birds. Some papers, however, have been published giving the total feather weight of birds. None whatsoever are available as to the calculated area of certain feathers. Also, there is the absence of material showing the relationships between feather number, the resultant feather weight and feather area to body weight. The factors affecting the relationship between feather number, feather weight and feather area to body weight may be breed characteristics, body size of individual birds, type of feathers (size - length and width -, structure - web and quill - and weight) or season of year at which the birds are plucked.

In order to establish some definite relationships in this hereto practically untouched field, this study was undertaken. It is one of the primary purposes of this paper to show these relationships simply and effectively.

It would be of material value to poultry research if some method could be devised whereby with a certain portion of the total feather weight, one could predict the bird's entire feather weight. If from measurements (length and width) of certain single feathers of the domestic fowl one could predict the total feather number, a tremendous saving of time in future feather research would be obtained. At the same time, it would be interesting to know the relationship between feather area and body weight.

As a minor part of this paper, surface area also comes in for due consideration. Surface area is minor because there should be more feathers on a larger bird since it has more skin surface from which feathers may grow. But surface area does not increase in direct proportion to body weight. Many investigators have suggested that surface area is equal to the 2/3 (.66) power of body weight. With birds of different sizes, surface area becomes smaller in proportion as body weight increases. A monumental example of this principle is found in the mouse and elephant. Certainly the elephant has less surface area in proportion to its body weight than does a mouse.

This paper deals with the above relationships, discussing those which proved to be most promising. Immediately this brings to mind numerous new possibilities for further study.

REVIEW OF LITERATURE

Slight attention has been given to the total number of feathers comprising the plumage of birds. Wetmore (1936) has reviewed the following feather counts:

> "Dwight in 1900 found 2325 feathers on a male Bobolink; McGregor in 1903 recorded 1899 feathers on a Savannah Sparrow and 6544 feathers on a Glaucous-winged Gull; Lowe in 1933 recorded 300 feathers to the square inch in the young of the Gentoo Pengium, but the total number for the bird was not given."

Wetmore's (1936) actual feather counts for 152 individuals, representing 21 families in passeriformes and related birds, varied from 940 in the Ruby-throated Hummingbird to 2973 feathers for a Southern Robin. Ammann (1937) reported 25,216 feathers on a Whistling Swan and 4342 feathers on a Yellow-headed Blackbird. This latter number is considerably higher than that of any passerine bird in Wetmore's list. A portion of this increase in feather number may be due to the larger size of the yellow-headed Blackbird and the excessively long neck of the swan.

Marsden and Martin (1939) state:

> "The U. S. Biological Survey counted approximately 4100 contour feathers on a 23-lb. yearling white tom, 5500 on a 10-lb yearling white hen, 4600 on a Black hen."

Communication with Miss Knappen suggested that these counts, as well as the following, were personally secured: A Bronze male - wild stock, had 4122 feathers, a White female with 5546 and a Black male had 5576 feathers. Miss Knappen found 3316 feathers on a Bobwhite and in 1932, she counted 11,093 feathers on an adult female Mallard. Included also, was a notation that 7878 feathers has been found on a ring-necked female peasant.

A few actual feather counts have been made with domestic fowl. Card (1923) states:

> "It has been variously estimated that there are from 3000 to 4000 feathers on a mature hen."

A cartoon appearing in the American Magazine, October, 1934, page 86 reads:

> "To settle an argument over the number of feathers on the average chicken, Vernon Thornburg, Barnsville, Ohio, dairy employee, killed and plucked a Plymouth Rock. He reported 8325 feathers."

A similar account is found in Time Magazine, November 5, 1934, page 66:

> "In Deering, Mo., to settle an argument among his schoolmates, Vernon Davis killed a chicken, counted 8537 feathers on it."

As an explanation for figure 73, page 151 in Marketing Poultry Products, Benjamin and Pierce (1937) state:

> "There are about 8000 feathers on a chicken or fowl."

Greenwood and Burns (1940) counted the molted feathers from 3 adult Brown Leghorn capons and reported 6773, 7118 and 7525 respectively. This favorably compares with the 6356 and 7250 feathers found on their two control capons.

In brief, a number of species were counted between the sparrow with 1899 and the swan having 25,216 feathers. Four of the 6 turkeys had similar counts of approximately 5500 feathers each. In the domestic fowl, both Thornburg (1934) and Davis (1934) agree with Benjamin and Pierce (1937) who say:

> "There are about 8000 feathers on a chicken or fowl."

The feather number found on the Brown Leghorn (Greenwood and Burns, 1940) was lower.

Studies in which the feather weight of domestic fowl is expressed as a percentage of body weight are more numerous. Mairs (1908) with

White Wyandotte, White Leghorn, Light Brahma and Barred Plymouth Rock cockerels and pullets, slaughtered at 26 weeks, found the feather weight of an average of 11 cockerels to be 8.36 to 9.11 percent of body weight. For an average of 8 pullets, this percentage was 6.07 to 9.38 percent of the body weight.

The following year, with a smaller number of individuals in each of these breeds and also with Buff Cochins and Rhode Island Reds, (killed approximately at 26 weeks because "the same plan was followed as in 1906") the reported percentages for cockerels and pullets was 4.83 to 6.75 and 5.70 to 6.57 percents, respectively. For both sexes, these percentages are much lower than those obtained the previous year. Jackson and Mitchell (1912) with the slaughtering weight of 144 Single Comb White Leghorns, ranging from 2 to 3 pounds, found the average feather weight was 9.24 percent of the initial body weight.

Kaupp (1916) found that the feathers of 5 three-year-old cocks and 16 hens at the same age, averaged 3.78 and 4.53 percent of their live body weight. Payne (1917) reported the body feathers of a single 6.75 pound roaster was 4.20 percent of the live body weight, while the wing and tail feathers comprised only 1.30 percent. Maw (1921) after killing 4 Barred Plymouth Rocks cockerels, which had been fattened 14 days, concluded:

> "the blood and feathers of large size chickens (over 3.5 pounds) equal 5.8 and 3.1 per cent of the live fattened weight."

In checking the original data, this must be a typographical error because the blood weight and feather weight percentages are 3.16 and 5.82 percent respectively. Additional data by Maw (1921) records the feather weight in five Barred Plymouth Rocks as 6.18 percent of body weight at the same fattened weight.

With Rhode Island Reds, Plymouth Rocks and Wyandottes, Hepburn and co-workers (1922) secured the following ratios when feather weight was divided by body weight. With 126 broilers averaging 1.9 pounds, 12 springs at 3.4 pounds, 18 roosters weighing 4.6 pounds and 48 hens averaging 4.9 pounds all fed on growing ranges, the recorded percentages were 6.67, 7.81, 8.42 and 5.33 respectively. Again, slightly larger birds having similar numbers in each of these four groups, fed the control ration, gave somewhat lower percentages, namely 6.45, 7.78, 6.75 and 4.85. Therefore, there is a somewhat lower dressing loss in birds fattened in batteries.

Card (1923) reported that feather weights on White Plymouth Rocks at various ages show that a 0.5 pound cockerel has 1/3 ounce of feathers. They weigh slightly over an ounce by the time he weighs a 1.5 pounds. When he weighs 3 pounds, they have increased to 3 ounces. Card further states:

"the feathers on a mature hen weigh roughly a quarter of a pound."

Extensive feather weight data have been compiled throughout the growing period by Mitchell, Card and Hamilton (1926) on White Plymouth Rock cockerels, pullets and capons with an average of five birds in each group. Observations were made at the approximate slaughtering weights 0.5 to 7.0 pounds for cockerels, from 2.0 to 5.0 pounds for pullets, and from 3.0 to 7.0 pounds for capons. Up to and after 2.0 pounds, the gradations increased by 0.5 and one pound intervals respectively. Due to sex differences, these three groups of birds did not reach the same approximate slaughtering weight at the same age in days.

The feather weight of cockerels averaged 5.79 of the live body weight. The recorded average feather percentage for the pullets was

7.59 percent, while 7.35 percent of the capon's live body weight was feathers. Later, these investigators (1931) showed that the feathers of 10 Single Comb White Leghorn cockerels from 0.5 to 5.0 pounds, averaged 7.35 percent of the live body weight. Similarily, pullets up to 4.0 pound were found to average 7.48 percent of their live body weight.

Horowitz (1931 and 1934) showed the feather weight of capons of the Polish Greenleg, which is a relatively small bodied bird, to be 613 to 7.42 percent of body weight, while the feather weight for cocks of the same breed was only 4.43 to 5.72 percent of body weight.

Benedict and Lee's (1937) review included:

> "normal hens have been found by Carpenter (in 1929) to have, on the average, 7.3 per cent of their weight in feathers."

Phillips, Ashworth and Brody (1932) showed that the feathers on 2 fasting hens were 5.28 and 6.55 percent of their initial weights. Fronda and Marcelo (1939) studying Los Banos Cantonese males and females, with 10 birds in each age group, found the following results:

	MALES		FEMALES	
Age	Body Wt. (Grs.)	Feathers as a % of Live Body Wt.	Body Wt. (Grs.)	Feathers as a % of Live Body Wt.
At Hatching	29.1	3.78	30.9	3.56
At 2 Months	331.3	7.76	340.8	5.96
At 4 Months	768.9	8.75	797.9	7.67
At 6 Months	1064.0	7.11	1096.9	6.73
At 8 Months	1148.5	6.94	1339.0	7.04

Although these numerous data showed wide variations, they closely agree with Lippincott and Card (1939) who state:

> "feathers make up from 4 to 9 per cent of the empty live weight, depending on the age and sex of the individual."

Partially due to a larger body, males have a greater feather weight than females. The ratio of feather weight to body weight varies throughout growth. From data of hatching, the percentage increases to 4 months for both males and females (Fronda and Marcelo, 1939). Thereafter, it decreases with continued age.

In other domestic poultry, several reports have been published in which feather weight is expressed as a percent of body weight. Benedict and Lee (1937) showed that 7 young and 10 adult geese (after fasting from 6 to 34 days) averaged 5.2 and 8.3 percent of their initial weights. For 3 normal geese (not fasting), an average of 4.2 percent was noted. A literature review by these writers shows that:

> "Boussingault in 1845 reported that the feathers of his normal adult geese averaged 9 per cent of their body weights; the 2 normal and 6 stuffed geese (all adults) of Schulze in (1882) had feathers weighing from 5 to 12 per cent of their initial weights. The proportion of feathers to total weight (4 to 7 per cent) in the adult normal and stuffed geese studied by Chaniewski in 1884 were more nearly like the percentages noted with our geese."

Unpublished measurements by Riddle - data published by Benedict and Lee - indicate that in general, the feathers of the common pigeon and ring dove, both adult and young, represent not far from 8 per cent of the total body weight.

Brody (1938) summarizing the available feather data from the literature; the domestic fowl data from Mitchell, Card and Hamilton; pigeon and dove data from Riddle; geese data from Benedict and Lee; passeriformes data from Wetmore, as well as that from Hutt and Ball, concluded that in each of these species, feather weight is practically proportional to body weight, rather than with surface area.

> "In growing domestic fowl, feather weight tends to vary with 1.0 power of body weight. In pigeons and geese, total feather weight tends to vary with the 0.9 power of body weight. In passeriformes of different species (age unknown, probably mature), contour feather weight tends to vary directly with body weight as in the growing domestic fowl. Contour feather number tends to vary with approximately the 0.2 power of body weight as previously reported by Hull and Ball, (1938)."

MATERIALS AND METHODS

For this investigation, male birds of seven varieites were studied, namely; Dark Cornish Bantam, Darl Cornish, Rhode Island Red, Crossbred (Rhode Island Red male x Dark Cornish female), White Wyandotte, Barred Plymouth Rock and White Plymouth Rock. To avoid repetition, as well as the possibility of these terms becoming cumbersome throughout the discussion, the variety names will be simplified. Hereafter, these varieties will be abbreviated to Bantams, Cornish, Reds, Crossbreds, Wyandottes, Barred Rocks and White Rocks, respectively. However, in all tabular data the complete variety name will be used.

These birds were hatched and individually wing banded by the poultry department in the spring of 1939. Previous to the experiment, each variety had been yarded separately in groups of twenty birds on growing ranges at the College Poultry Farm. During early fall, the birds were transferred to winter shelters. Throughout this time, feeding and management was similar for all seven varieties. Previous to plucking, all birds had attained the age of ten months.

Most poultry investigators believe the domestic fowl has reached its maximum weight and has fully developed all their adult characters by ten months of age. This study, then, was conducted largely with adult birds. Additional work, however, is included to show the relationship of one adult character (feather weight) to age and sex. Separately this information was secured from capons and cockerels. Later, at its applicable point, it will be included and discussed in relation to this paper.

Preliminary collection of the original data began November 11, 1939. While the majority of the work was done during the latter third of

December, the study was practically completed by the eighth of January. However, 7 birds (3 being White Rocks) were plucked in the fore part of March.

To avoid the possibility of securing non uniform results due to unorganized methods and personal variation while collecting data, a definite procedure was followed throughout this research. To eliminate the influence of age, one male of each variety was plucked in rotation. This plan was continued throughout the experiment.

By observation and examination, only those birds in good body condition were selected. Unless conditions of feed and housing are adequate, the body weight of the domestic fowl is lessened through the winter. Although there were major fluctuations in the temperature outside the coops during the period of observation, the birds in each variety had similar body weights at the beginning and close of the experiment. Those few birds plucked in March were of the same general body condition as those selected earlier.

Prior to slaughtering, each bird was placed in a wire cage approximately 12 hours without feed. After the live body weight had been recorded, care was taken by an assistant, Mr. Howard Connally, to ensure complete bleeding and debraining. All records, including selection of the first primary, first secondary, and fourth tail feathers (all from the right sides) were made by the writer. The primary and secondary feathers were numbered from the axial feather, while the tail feather was latered from the median line of the body. These selected feathers were labelled and temporarily set aside for later study, followed by the removal and counting of the remaining tail and wing feathers. The remainder of the plucking was also completed by the writer. Mr. Connally aided materially by helping count the feathers and recording the progressive feather count on an automatic hand tally..

To aid in counting the feathers, each bird was removed to a well lighted room after the bled body weight was recorded. An available table was covered with colored paper which contrasted strongly against the quill of each feather. Only those feathers containing a quill and a definite web were counted. The loose, numerous after-shafts, as well as the down and filoplumes, were not included. Careful note was made to see that possible feathers with broken quills from the wing and tail tracts were temporarily set aside. After the bird was completely picked, these broken shafts were removed from the feather follicles and the feathers with broken quills were counted. As a rule, due to the good debraining, very few shafts were broken.

Throughout this study, periods of actual feather counts at one sitting were of short duration depending upon the type of feathers (neck, wing, back or leg) being counted and their ease of separation. This prevented error, due to fatigue, from entering into the tabulations. At first the feathers on only one bird were counted in a day. As efficiency and technique improved, it was possible on many occasions to feather-count 2 birds per day.

Starting with the right wing, feathers were picked and placed quill-first toward the assistant, who separated them into convenient groups of 2, 3, 4 or 5 and rapidly recorded them on the hand tabulator. While the feather count was progressing, the remaining feathers on the leg, breast, and a portion of the fluff were pulled. This same procedure was continued on the left side, followed by the pulling of the remaining fluff and back feathers. On many occasions, the writer would count small groups and conveniently announce this number, paying special attention that they were being correctly recorded by the familiar "click" of the tabulator. As each group of feathers were counted, they were carefully brushed from the table through a large paper funnel into a cotton bag for weighing.

When the feathers up to and including the anterior edge of the wings were picked, 1/3 of the distance from a point at the insertion of the humerus bone to the anterior end of the beak was calculated and carefully marked. Throughout the discussion, this portion of the neck will be spoken of as 1/3 of the measured neck length.

This point was arbitrarily chosen for several reasons: In the preliminary study it was found that the feather count on the head and extreme upper neck regions was highly sensitive to error. Losses occured through failure of proper feather identification, because of broken quills and also due to the tedious task of thorough plucking even though fine tweezers were used. In these regions there is no definite segregating area between the minute feathers. Thus, prolonged effort was liable, through fatigue, to lead to error.

There was need to count the feathers on a large group of birds within each variety to secure a representative study. To ensure this, the time element and the limited availability of the selected varieties made it a practical impossibility to count all the head and neck feathers.

A third reason for selecting this relative point was that feathers are not so numerous in this area and the point can be measured and accurately marked. Therefore, unless those birds with longer necks have more feathers than birds with shorter necks (body weight similar) a uniform feather count should be obtained.

When all of the feathers up to this point had been counted, a final observation was made of the entire body to count those small feathers, including the pin feathers, which might have been possibly overlooked at first plucking. A check was made to see that no loss occured by feathers falling from the table to the floor. As soon as the last feather was counted, the feather number was immediately recorded. This portion of the total feathers, including the wing and tail feathers, was weighed and recorded. The remaining feathers on the neck and head, although not counted, were plucked and weighed with the previous lot to obtain the bird's total feather weight.

To see if there is a correlation between feather number, weight or size (length and width) and body weight, two measurements were made on the first primary, first secondary and fourth tail feathers. Entire length of the plucked feather and maximum width of the web was measured. These feathers were selected because of their ease of identification; they are well protected from injury due to their respective feather tract locations, resulting in uniform measurements for all birds. This is especially true of the wing feathers. Frequently the first two or three tail feathers were broken or missing, thus resulting in the final selection of the fourth.

RESULTS

Body Weight Versus Surface Area

It is generally known that surface area per unit body weight tends to decline with increasing weight of the animal. This decline is ordinarily explained the fact that with increased body weight, surface area doesn't proportionally increase at the same rate. Two extreme differences can be observed between the elephant and mouse. Certainly the elephant has far less surface area in proportion to its weight than does the mouse.

It has been suggested that surface area is directly proportional to some power of the body weight. To show this relationship, Meeh as reported by Brody (1928), suggests the formula: $S = kW^{2/3}$; where S = surface area and W is body weight, k and the figure 2/3 are constants. The numerical value of constant k is dependent upon the unit of weight employed and the specific gravity of the animal. The numerical value of n (2/3 in the above formula) is dependent upon the animal's shape and the change in the specific gravity of the animal due to change in weight. Only when the body is spherical does the value of the power equal .66. Some investigators have assumed this value of n also to be true for animals. However, since animals are not spherical, this may not be the case.

Brody (1928) suggests this value of the power to vary from 0.32 to 0.72, depending upon the form of the animal. One of the changes in form of the animal is due to increase in weight during growth. Other changes in the form of mature animals results from fattening or fasting. Thus, the lowest value of the power is related to fattening, while the highest is for growth (Brody, 1928).

If the correct value of the power is 0.66, then the above formula is the simplest formula relating surface area to body weight. Hence, it is the most practical method of showing the relationship if and when a reasonable degree of accuracy can be secured through its use as a prediction formula. But Brody (1928) says:

> "the use of a prediction formula (necessarily formulated on the basis of measurements of a population) for estimating the surface area of an individual may involve an error as high as 10 per cent of the true value."

Due to the possibility of such a high error, it seems that this method is hardly justifiable.

Whatever the decision, surface area is a derived value from body weight and often uncertain. However, the use of surface area as a practical unit of reference may be justifiable as far as humans are concerned. Largely this is due to grounds of established usage. Also, because the empirical formula seems to have been established indeed with much precision and accuracy. At any rate, the relationship between body weight and surface area in humans is widely accepted.

But regards farm or laboratory animals, this is not true. Brody (1932) showed that determinations of surface area for one species by different investigators may vary by more than 60 percent. What is the use of relating a factor to a unit of reference which varies by over 60 percent when measured by different investigators? Why not relate it to weight which can be measured uniformly by all workers with a precision greater than 99 percent (Brody, 1932)?

If, through an exacting and time-consuming method, surface area determinations are made on a large number of individuals they should have a definite value. There is no scientific value in a method (of expressing surface area as a power of body weight) where there is a possibility of such a large error. Nor is there quality in the burdened literature if the results secured are not empirically sound. These conditions must be avoided if surface area determinations are to be of significant value.

Mitchell (1930) who endorsed the use of surface area as a unit of reference, admitted that:

> "the surface area is not a definite measurement, but depends to a considerable extent upon the shape of the body as determined by the position of the body trunk and its appendages."

Since there is a possibility of realizing a large error in the derivation of surface area from body weight, would actual surface measurements solve the problem? But a square meter of body surface would possess no absolute meaning unless the surface measurements for different animals are made by exactly the same method. It is a practical impossibility to measure widely different species by exactly the same method. Especially so, since the measurements are made by different investigators in that many localities.

This is the practical objection against the use of surface area as a unit of reference, at least in nonhumans. Besides, if feather number, feather weight and feather size are proportional to surface area, and area is a function of body weight, then feather number, weight and size are likewise functions of body weight. There seems to be no reasonable advantage in relating feather number, feather weight or feather size to surface area, which area is computed from weight, when they might be related directly to weight. Especially this is true since it has not been proved that feather number, feather weight and feather size are directly proportional to surface area in adult domesticated fowl. Brody (1938) says:

"that neither feather number nor feather weight is proportional to surface area."

Throughout the literature many investigators have determined different values for the k constant for deriving surface area from weight from the formula, $S = kW^n$. Giaga, as reported by Hutt and Ball (1938), previously determined the value of k to be from 6.54 to 11.5 for chickens of different sizes. For Single Comb White Leghorn chickens (both sexes) Mitchell, Card and Hamilton (1931) reported their k value at 10.39. Their derived value for White Plymouth Rocks (1926) was 10.64. These investigators futher suggested that it would be profitable if a separate k value for each sex was calculated. Since so many values have already been previously determined for the k value in this formula, it is doubtful if it would be justifiable to determine surface area from body weight.

Brody (1938) reported that total feather weight is proportional to body weight. In the formula $Y = aX^n$; where Y = feather weight and X = body weight, n was 1.2 for growing domestic fowls. For feather number, the n value was 0.2 (Hutt and Ball, 1938). Brody (1938) says:

"Neither feather weight nor feather number is proportional to surface area."

By the method of least squares (Feldstem and Hersh, 1935), the data was fitted to the above formula. The n value for feather weight on mature fowls was 1.256. The value of n for feather number was 0.163. These values are almost identical with those previously reported by Brody (1938) and Hutt and Ball (1938). Brody's (1938) n value was on growing domestic fowl, while that of Hutt and Ball (1938) was on (probably mature) wild birds. Because of such similarities, it may be further concluded that feather weight and feather number in mature domestic fowl are proportional to body weight, not surface area.

The arguments in favor of relating feather number, feather weight and feather size to body weight rather than surface area are then, first, rationality; rational because each of the constants are clearly defined. Second, this method eliminates the use of the uncertain surface area as a unit of reference. Third, this type of reasoning is familiar to research. Fourth, results independently obtained agree with previous findings.

For these reasons, feather number, feather weight and feather size are considered in relation to body weight and not to surface area.

Variety Comparison of Individual Body Weights

Listed in increasing order are the Standard, mean body weights of the different varieties.

Variety	*Standard Cockerel Body Weight pounds	Mean Body Weight pounds	Body Weight Range pounds
Dark Cornish Bantam	1.87	3.38	0.57
Dark Cornish	8.50	6.55	0.94
Crossbred		6.73	1.35
White Wyandotte	7.50	6.74	0.85
Barred Plymouth Rock	8.00	7.65	0.91
Rhode Island Red	7.50	8.13	1.34
White Plymouth Rock	8.00	8.20	2.07

*American Standard of Perfection 1938.

The smallest variety studied was the Bantams. With a similar body conformation, the average body weight of the Cornish was 6.55 pounds, which was approximately 3 pounds larger than the weight of the Bantams. The Barred Rock's mean body weight of 7.65 pounds was one pound greater than the weight of the Wyandottes and Crossbreds. The Wyandottes had the highest average body weight, 8.20 pounds, although the weight of the Reds was almost as high.

There is less range in the Standard variety weight than the varieties exhibited. Thus, the mean body weights of the Bantams, Reds, and White Rocks were larger than the Standard (1938) cockerel weights.

The body weight range in some varieties was slight, others large. The lowest range was found in the Bantams and Wyandottes. The ranges of the Barred Rocks and Cornish were similar. The differences within the Reds and Crossbreds amounted to 1.34 pounds. The largest range, 2.07 pounds, was found in the White Rocks.

It was desirable to see if these observed differences between the varieties and between individuals within the varieties were significant. Below are the data of the analysis of variance of body weight.

Analysis of Variance of Body Weight

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	33	88.56	
Between the Varieties	6	78.22	13.03*
Within the Varieties	27	10.34	3.83

*significant

Analysis of variance showed the following: There was more variation in body weight between the means of these varieties than there was between the individuals within the varieties. These differences in body weight are significant. In other words, there was more variation between the means of the varieties than there was between the individuals within the varieties. In Snedecor's (1938) F-test, the values at the 5 and 1% levels are considered significant and highly significant respectively. A body weight difference of 2.53 pounds is necessary between the means of these varieties to be significant. To be highly significant, 3.41 pounds are required.

Although the Dark Cornish are larger than the Bantams, the difference in their body weights is barely significant. Because of the extreme differences in body size between the Bantams and the 5 remaining larger varieties, a highly significant difference was found. However, the differences of the Crossbreds and Wyandottes were just approaching this level, or were on the borderline of being highly significant. Due to a similar body weight for each of the large varieties, a nonsignificant difference was found between their mean body weights. Within a variety, the only variation present is random variation.

Relationship Between Feather Number and Body Weight

The difference in body outline between breeds of domestic fowl is partially due to the closeness in which the contour feathers adhere to the body. Other factors affecting the usual contour feather outline of the bird may be feather number, as well as structure. Plumage outline differences are observed between the Wyandottes and Cornish. There is an abundance of loose, fluffy feathers in the former, while in the Cornish, they lie very close to the body. The "feather type" of the other breeds in this study fall between these extremes in closeness with which they lie on the body. Following is the average feather number for each variety listed in increasing order:

Variety	Mean Feather Number	Feather Number Range
Dark Cornish Bantam	4882	927
Barred Plymouth Rock	5550	333
White Plymouth Rock	5578	852
Crossbred	5691	708
Dark Cornish	5725	490
Rhode Island Red	5874	680
White Wyandotte	5988	756

The Bantams had the lowest average recorded feather number, 4882. The Bantam's body weight has been reduced by about one-half that of the Cornish. Thus, their mean feather number is approximately 1/7 lower than the number found on their larger sister variety. The smallest number of feathers counted in this experiment, 4369, was also found in this variety. The two varieties of Plymouth Rocks had almost identical means. They were 5550 and 5578 feathers respectively. The latter number was found in the White Rocks, which was the larger variety. Excluding the Bantams, the 3 lowest counts were found in the White Rocks, Crossbreds and Barred Rocks. They were 5170, 5343 and 5345 feathers respectively. Like the latter two numbers, another (5368) was also found in the White Rocks.

The Crossbreds and Cornish had almost similar means with approximately 5700 feathers each. Thus, the Crossbreds tended to approach their Cornish dam in feather number. These two means are more like those recorded for the Plymouth Rock varieties than was any other variety. There was a difference of 114 feathers between the average feather number of the Reds and Wyandottes. For the former variety, their mean count being smaller, was 5874, while that of the Wyandottes was 5988 feathers. These comparisons show that the mean feather number within the varieties appear distinct. Feather number, therefore, may account for the visual plumage differences within varieties.

The least range in feather number between varieties was found in the Barred Rocks and Cornish. Varieties having a range between the extreme differences were Reds, Crossbreds and Wyandottes. The ranges of the two former varieties were almost similar, being 680 and 708 feathers respectively. The range within the Barred Rocks was slightly larger. However, the greatest range, 927 feathers, was found in the Bantams. Between individuals, within a variety, there were both large and small feather number ranges.

From the smallest feather number (4363) to the largest (6379) there was a difference of 2016 feathers. Within this range, it was noted that several birds had a similar number of feathers.

A grouping of the 34 birds into classes of increasing feather number are as follows:

Feather Number Class	Number of Birds in Each	
4000-4500	1	1 bird had approximately 4400 feathers
4500-5000	2	2 birds had approximately 4800 feathers each
5000-5500	8	3 " " " 5300 " "
5500-6000	16	7 " " " 5600 " "
6000-6500	7	4 " " " 6000 " "

Table I includes the mean and individual age in weeks, body weight and feather number for each variety. Immediately, the similarities and differences of these three factors between each variety and between individuals within each variety can be noted. From these data, the analysis of variance and covariance was made.

To see if the mean differences in feather number were mathematically significant, an analysis of variance was made. Below are the completed results.

Analysis of Variance of Feather Number

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	33	6,042,096.95	
Between the Varieties	6	3,827,859.35	637,976.50**
Within the Varieties	27	2,214,237.60	82,008.80

**highly significant

The analysis of variance showed that the variation in feather number between the means of these varieties was greater than that between the individuals within the varieties. This difference between

Table I

The Mean, Individual Age in Weeks, Body Weight and Feather Number for Each Variety

Dark Cornish Bantam

		Age In Weeks	Body Weight pounds	Feather Number
Mean		43	3.38	4882
	1.	(41)	3.26	5290
	2.	(42)	3.33	5204
Bird	3.	40	3.35	4708
	4.	(43)	3.11	4844
	5.	50	3.83	4363

Barred Plymouth Rock

		Age In Weeks	Body Weight pounds	Feather Number
Mean		46	7.65	5550
	1.	42	8.00	5678
	2.	45	8.02	5623
Bird	3.	47	7.38	5621
	4.	47	7.11	5483
	5.	51	7.75	5345

White Plymouth Rock

		Age In Weeks	Body Weight pounds	Feather Number
Mean		49	8.20	5578
	1.	44	7.70	5524
	2.	47	7.75	5809
Bird	3.	52	8.60	5170
	4.	52	7.43	6022
	5.	53	9.50	5368

Crossbred

		Age In Weeks	Body Weight pounds	Feather Number
Mean		43	6.73	5691
	1.	42	7.40	6051
	2.	44	6.33	5753
Bird	3.	41	7.13	5617
	4.	44	6.05	5343

Table I, continued

	Dark Cornish				Rhode Island Red		
		Age In Weeks	Body Weight pounds	Feather Number	Age In Weeks	Body Weight pounds	Feather Number
Mean		44	6.55	5725	47	8.13	5874
	1.	44	6.71	5617	1. 45	7.86	5693
	2.	40	6.80	5705	2. (46)	7.75	5953
Bird	3.	45	6.32	5784	3. 44	9.09	6169
	4.	46	6.92	5514	4. 47	7.92	6066
	5.	47	5.98	6004	5. 53	8.05	5489

White Wyandottes

		Age In Weeks	Body Weight pounds	Feather Number
Mean		49	6.74	5988
	1.	47	6.64	6234
	2.	48	7.25	6379
Bird	3.	47	6.95	5623
	4.	49	6.48	5830
	5.	54	6.40	5872

the means of varieties is highly significant. According to Snedecor's (1938) F-test, at the 5% level, a difference of 371 feathers between the means is necessary to be significant. For a highly significant difference, or at the 1% level, 502 feathers are required.

Because of the vast difference in size between the Bantams and the remaining 6 larger varieties, there was a highly significant difference between their means. Since the range in the body weight of the larger varieties was not as great, the highest feather mean was necessary before a significant difference was found. The difference between the means of the Barred Rocks and Wyandottes is significant. Beyond the Bantams and the Barred Rocks, the differences between the means of the 5 remaining varieties are nonsignificant.

From the data presented in Table I, no definite relationship can be noted between body weight and feather number. In some varieties (Barred Rocks), there was a slight downward trend in feather number and body weight as the experiment progressed. In others (Reds), this trend was upward. To find the possible correlation between feather number and body weight, the analysis of covariance was completed. Table II includes the computed data.

Due to the extreme differences in body weight between the Bantams and the White Rocks, their body weights were adjusted to a common mean. In analysis of covariance, this permits a temporary variety containing 34 individuals. Thus, the varability between individuals within a variety (varieties) can be readily detected.

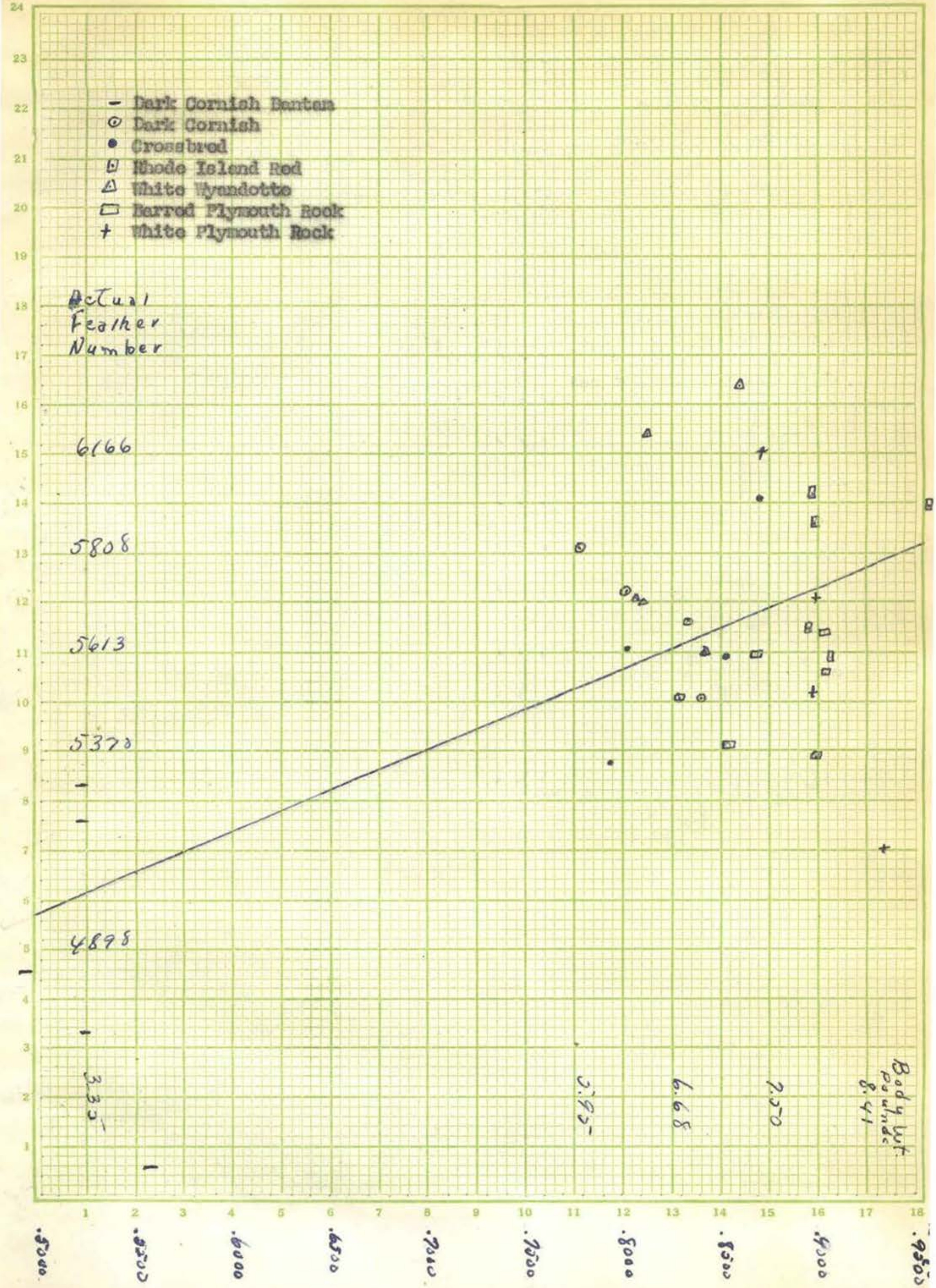
After adjusting for body weight, the difference in feather number between varieties is highly significant. The variation between the means of the varieties is greater than that between the individuals within

Table II

Analysis of Covariance of Body Weight (X) and Feather Number (Y)

Source of Variation	Degrees of Freedom	Sums of Squares and Products			Error of Estimate			Correlation Coefficient
		SX^2	SXY	SY^2	Sum of Squares	Degrees of Freedom	Mean Square	
Total	33	88.56	13,043.54	6,042,096.95	4,120,982.05	32		.564**
Between the Varieties	6	78.22	13,475.26	3,827,859.35	1,924,769.80	6	320,794.90	
Within the Varieties	27	10.34	- 431.72	2,214,327.60	2,196,212.25	26	84,469.70	-.090

**highly significant



— Dark Cornish Bantam
⊙ Dark Cornish
• Crossbred
⊡ Rhode Island Red
△ White Wyandotte
▭ Barred Plymouth Rock
+ White Plymouth Rock
Actual Feather Number
6166
5808
5613
5370
4898
3.30
5.95
6.68
7.70
8.41
Body wt. pounds
.5000
.5500
.6000
.6500
.7000
.7500
.8000
.8500
.9000
.9500

varieties. Through the analysis of covariance, a correlation coefficient of .564 was found for the total number of birds. This correlation is highly significant.

To test the possible correlation of body weight and feather number between individuals within a variety, a new coefficient was determined. The correlation between individuals within a variety was -.090. This correlation value is negative. A negative correlation suggests that there is a nonsignificant variation in feather number between individuals within a variety.

Seasonal Variation in Feather Number

A total of 7 birds, representing 5 of the 7 varieties were plucked during the first half of March. Of these 7 birds, 3 were White Rocks and there was one in each of the following varieties: Bantams, Reds, Wyandottes and Barred Rocks. In every case except the Wyandottes, these March plucked birds had the minimum feather number for each of their respective varieties. In this differing variety, there were 2 other birds (not plucked in March) that had a smaller number of feathers. One differed by 42 feathers, while the second had 249 less feathers. These minimum feather numbers of the Barred Rocks, Reds and Bantams were approximately 100,200 and 400 feathers smaller respectively than those of other birds.

This suggests the possibility that at this season there may be a tendency for male birds to start molting (Greenwood and Burns, 1940). This assumption is true for each of those varieties having a number plucked in March. It is strengthened in the 3 White Rocks which were plucked at this time. Two of these 3 March plucked birds had the two lowest feather numbers, while the third had the highest. There was no indication in the data accounting for this discrepancy.

For each individual within a variety, feather number was plotted against body weight in logarithms. The results are shown in Graph I (p. 27). It shows the distribution of all birds above and below the regression line. As expected, there is an equal distribution of individuals above this line. Due to a smaller feather number and body weight, the Bantams are entirely superated from the other 5 varieties. As a group, the Barred Rocks were the only variety which were not distributed above and below the regression line. All the individuals fell below this line.

Relationship Between Counted Feather Weight and Body Weight

That portion of the total feathers up to and including 1/3 of the measured neck length were counted. Weight of these counted feathers was recorded. Later, upon completion of the total plucking, all of the feathers on the body were weighed. It was desirable to see what relationship existed between these two groups of feather weights. Economically, time devoted to feather research would be more profitably utilized if some method was devised whereby one could predict the total feather weight from the weight of that portion of the total feather number up to this previously determined point.

The weight of the counted feathers, as well as the total feather weight, were both expressed as a per cent of live body weight. Since the total feather weight is greater, its percentage is also larger than the former. A new ratio was secured for each bird by dividing the smaller percentage by the larger. Averaging these 34 individual percentages, a mean ratio of 90.01% was secured. In checking, an almost identical percentage (90.16%) was obtained by following the same procedure for the mean weights of all the varieties. By averaging these percentages, a final ratio of 90.09% was found.

From this latter percentage, it may be concluded that the weight of the feathers up to and including 1/3 of the measured neck length will predict safely 90% of the total feather weight. Because of this reasoning and due to the fact that there may be a possibility of confusing the reader if both feather weights were discussed, it was decided that, singly, the counted feather weight would be a better indication of the relationship between body weight and feather weight.

Originally, the feathers were weighed in grams. Since body weight was expressed in pounds and to secure a comparable measure, the gram feather weight was converted to pounds. To insure conversion accuracy, the new feather weight in pounds was carried to the third place beyond the decimal.

Listed below in increasing order are the mean converted feather weights and corresponding ranges in feather weight for each variety:

Variety	Mean Feather Weight pounds	Feather Weight Range pounds
Dark Cornish Bantam	0.125	0.037
Dark Cornish	0.229	0.030
Crossbred	0.229	0.034
Barred Plymouth Rock	0.359	0.040
Rhode Island Red	0.374	0.073
White Wyandotte	0.408	0.038
White Plymouth Rock	0.411	0.025

The minimum counted feather weight mean, 0.129 pounds, was found in the smallest variety, Bantams. Although being a larger variety, but with a similar feather structure, the feather weight of the Cornish was almost twice that of the Bantams. By reducing the body size of the Cornish by one-half (Bantams) feather weight is also smaller by approximately one-half. The Crossbreds, no doubt, due to their Cornish female parent, had the next largest mean feather weight, 0.299 pounds.

It is interesting to note how closely this weight compares with the average of the two means of the parents. Actually the difference is only 0.002 pounds. Practically the mean feather weight of the Crossbreds is equal to the average feather weight of their parents.

If Crossbred progeny inherit half of their characters from each parent, then it would naturally follow that the next largest mean feather weight should belong to the Reds, providing this latter variety has a similar body size as other varieties in the experiment. The mean feather weight of the Reds was 0.374 pounds. This is somewhat larger than the recorded weight of the Barred Rocks.

Although the Wyandottes had the largest mean feather number, their feather weight was lower than that of the White Rocks. This latter variety being the largest in the study, had the highest mean feather weight, 0.411 pounds.

Between the Bantams and the White Rocks, which had the lowest and highest feather weight respectively, there was a difference of 0.286 pounds. This figure nearly coincides with the feather weight of the Crossbreds.

In comparing counted feather weights between individuals within varieties, it was found that the White Rocks and the Cornish showed the least range. Their ranges were above 0.025 pounds. The Crossbreds, Bantams and Wyandottes had somewhat larger ranges. Greater still, was that of the Barred Rocks, 0.040 pounds. The greatest feather weight range, 0.073 pounds, was found in the Reds. Between the Plymouth Rock varieties, there was a larger difference between their mean feather weights than in their almost identical mean feather numbers. A feather weight difference of 0.052 pounds was found. Only 28 feathers prevented their mean feather numbers from being the same.

Within these variety feather weight ranges, several birds had similar feather weights. Listed below are five feather weight classes and the number of birds found in each:

Feather Weight Class, pounds	Number of Birds	
0.110-0.150	5	5 were Dark Cornish Bantams
0.150-0.210	0	-
0.210-0.300	7	5 were Dark Cornish
0.300-0.400	12	4 " Rhode Island Reds
		5 " Barred Plymouth Rocks
0.400-0.426	10	5 " White Plymouth Rocks
		4 " White Wyandottes

From the data in Table III, the computed analysis of variance is:

Analysis of Variance of Counted Feather Weight

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	33	0.343	0.0556
Between the Varieties	6	0.334	0.0556**
Within the Varieties	27	0.009	0.0003

**highly significant

The analysis showed that there was more variation between the means of these varieties than there was between the individuals within these varieties. This difference between the means of varieties is highly significant. There was less variation between the individuals within a variety than there was between varieties. To show a significant difference, or at the 5% level between these varieties, a difference of 0.022 pounds is necessary. A larger feather weight, 0.030 pounds, is required to show a highly significant difference.

Although the Reds were considerably larger than the Barred Rocks, there was a nonsignificant difference between their mean feather weights. Since there was such a large difference between the mean feather weights of the Reds, Wyandottes and White Rocks, a highly significant difference

Table III

The Mean, Individual Age in Weeks, Body Weight and Feather Weight for Each Variety

Dark Cornish Bantam

	Age In Weeks	Body Weight pounds	Counted Feather Weight pounds
Mean	43	3.38	0.125
1.	(41)	3.26	0.149
2.	(42)	3.33	0.134
Bird 3.	40	3.35	0.115
4.	(43)	3.11	0.115
5.	50	3.83	0.112

Dark Cornish

	Age In Weeks	Body Weight pounds	Counted Feather Weight pounds
Mean	44	6.55	0.229
1.	44	6.71	0.243
2.	40	6.80	0.234
3.	45	6.32	0.234
4.	46	6.92	0.213
5.	47	5.98	0.223

Crossbred

	Age In Weeks	Body Weight pounds	Counted Feather Weight pounds
Mean	43	6.73	0.299
1.	42	7.40	0.306
2.	44	6.33	0.318
Bird 3.	41	7.13	0.289
4.	44	6.05	0.284

Barred Plymouth Rock

	Age In Weeks	Body Weight pounds	Counted Feather Weight pounds
Mean	47	7.65	0.359
1.	42	8.00	0.353
2.	45	8.02	0.373
3.	47	7.38	0.368
4.	47	7.11	0.368
5.	51	7.75	0.333

Table III, continued

	Rhode Island Red			White Wyandotte		
	Age In Weeks	Body Weight pounds	Counted Feather Weight pounds	Age In Weeks	Body Weight pounds	Counted Feather Weight pounds
Mean	47	8.13	0.374	49	6.74	0.408
1.	45	7.86	0.337	1. 47	6.64	0.417
2.	(46)	7.75	0.348	2. 48	7.25	0.419
Bird 3.	44	9.09	0.384	3. 47	6.95	0.381
4.	47	7.92	0.410	4. 49	6.48	0.406
5.	53	8.05	0.390	5. 54	6.40	0.417

White Plymouth Rocks

	Age In Weeks	Body Weight pounds	Counted Feather Weight pounds
Mean	50	8.20	0.411
1.	44	7.70	0.410
2.	47	7.75	0.417
Bird 3.	52	8.60	0.401
4.	52	7.43	0.401
5.	53	9.50	0.426

was found. However, due to the almost identical mean feather weights of these latter two breeds, a nonsignificant difference was naturally present. Even with a close resemblance in feather type between the Bantams, Cornish and Crossbreds, there was a highly significant difference between their varying mean feather weights. Considering the differences noted in the Reds and Barred Rocks, as well as the Wyandottes and White Rocks, there was a highly significant difference between the mean feather weights of all other varieties.

The counted feather weight of the varieties has already been shown to equal 90% of the total feather weight. The relationship could be seen even more readily when the analysis of variance was computed on the total feather weight. Since the counted feather weight is a part of the total feather weight, the same identical nonsignificant, significant and highly significant differences between the means of the several varieties was noted.

Since the total feather weight is always larger than any other weight portion up to this point, a larger variation is needed to show a nonsignificant, significant and highly significant difference between the variety feather weight means. When it is realized that increased feather weights of 0.002 and 0.003 pounds, at the 5 and 1% levels respectively are necessary to show a significant and highly significant difference between the variety means of these two weight groups, the dependency of total feather weight upon the latter is clearly seen.

Through analysis of variance the differences between varieties and between individuals within varieties were found. To determine the possible correlation between body weight and counted feather weight, the analysis of covariance was computed. The recorded data is presented in Table IV.

Table IV

Analysis of Covariance of Body Weight (X) and
Counted Feather Weight (W)

		Sums of Squares and Products			Error of Estimate			
Source of Variation	Degrees of Freedom	SX^2	SXW	SW^2	Sum of Squares	Degrees of Freedom	Mean Square	Correlation Coefficient
Total	33	88.56	4.621	0.343	0.01400	32		.83850**
Between the Varieties	6	78.22	4.588	0.334	0.00504	6	0.000840	
Within the Varieties	27	10.34	0.033	0.009	0.00896	26	0.000345	.10819

**highly significant

Due to the extreme ranges in body weight between the varieties, it was necessary to adjust body size to a common mean. After removing influence of size, the mean counted feather weight differences between varieties was nonsignificant. Between body size and counted feather weight, a highly significant correlation, .839, was found for all the birds.

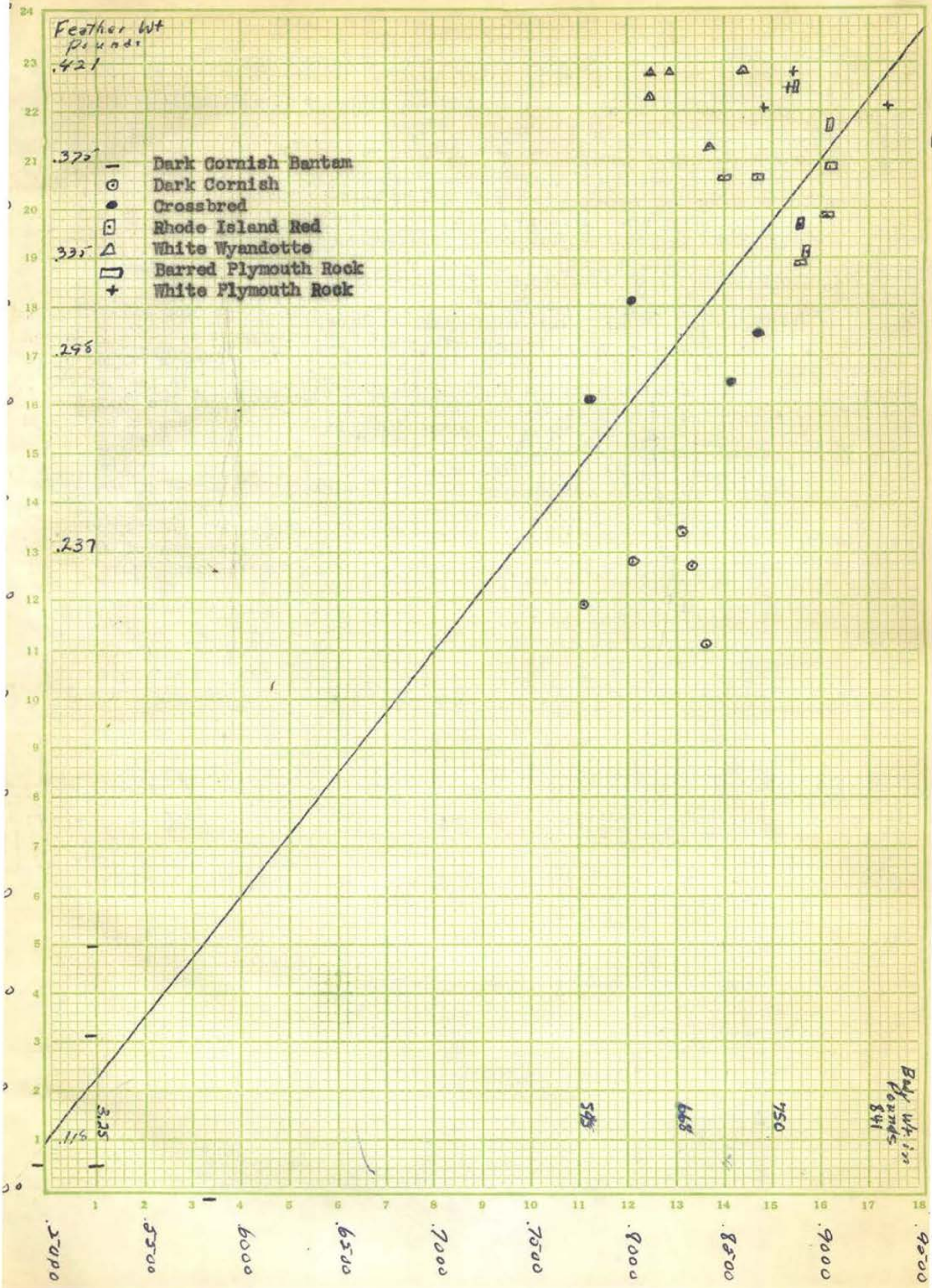
Between body weight and feather weight within varieties, a correlation of .108 was found. This correlation is nonsignificant. Within varieties there is a nonsignificant correlation between body size and feather weight.

Like feather number, feather weight was plotted against body weight in logrithims for each individual. The data are given in Graph II (p. 36). Because of the smaller feather and body weights of the Bantams, they are not near the larger varieties. As a group both the Cornish and the Wyandottes did not fall above and below the regression line. All the Wyandottes were above, while the former were below. Both the Cornish and Wyandottes had the smallest and largest meansfeather weights. Thus, there is a difference in the feathers of these two varieties.

Seasonal Variation in Feather Weight

Of the 7 birds plucked in March, the variety minimum feather weights were found in the inclusive members of the Bantams, Barred Rocks and White Rocks. With 3 White Rocks being plucked at this time, their maximum feather weight was also found in March. Similarly, the Reds and Wyandottes approached this relationship.

Due to the fact that the remaining 27 birds in the experiment were plucked over such a short period of time, there is no starting point whereby seasonal comparisons between the breeds can be attempted.



Feather Wt Pounds
.421
.372
.335
.298
.237
.115
Dark Cornish Bantam
Dark Cornish
Crossbred
Rhode Island Red
White Wyandotte
Barred Plymouth Rock
White Plymouth Rock
3.25
545
668
750
841
Body Wt in Pounds
.5000
.5500
.6000
.6500
.7000
.7500
.8000
.8500
.9000
.9500

Since the 7 March plucked birds so evenly possessed their variety maximum and minimum feather weights, there was no relationship between feather weight and the season of the year at which they are plucked. Further study, involving a greater seasonal range with a larger number of birds than was here available, will be necessary to show this relationship.

Relationship Between Feather Number and Feather Weight

Since it has already been shown that there is a highly significant correlation between body weight and feather number, as well as body weight and counted feather weight, is feather weight dependent upon feather number? In Table V are included the mean and individual feather number, counted feather weight and weight per counted feather for each variety. In both the Bantams and the Wyandottes, the maximum feather weights were found on those birds having the maximum and minimum feather number respectively. This same tendency was also evident in other breeds, but birds having a similar feather number, feather weight differences were no greater than 0.02 pounds.

Except for a slightly lower feather weight, the Cornish and Crossbred's maximum feather weight also resulted from the largest feather number. Otherwise, their relationship was the same as for the Bantams and Wyandottes. For the White and Barred Rocks, the smallest feather weight also resulted from the minimum feather number. From these groups it will be noted that in all the breeds except one (Reds), the minimum feather weight was found on the individual having the smallest number of feathers.

In some varieties, the opposite relationship was noted. In the White Rocks, the minimum feather weight definitely resulted from the

Table V

The Mean, Individual Feather Number, Feather Weight and Weight Per Counted Feather for Each Variety

	Dark Cornish Bantam			Dark Cornish		
	Feather Number	Counted Feather Weight	Weight per Counted Feather 1/10,000 pounds	Feather Number	Counted Feather Weight	Weight per Counted Feather 1/10,000 pounds
Mean	4882	0.125	.256	5725	0.229	.400
1.	5290	0.149	.282	5617	0.243	.433
2.	5204	0.134	.257	5705	0.234	.410
3.	4708	0.115	.244	5784	0.234	.405
4.	4844	0.115	.237	5514	0.213	.386
5.	4363	0.112	.257	6004	0.223	.371

	Crossbred			Rhode Island Red		
	Feather Number	Counted Feather Weight	Weight per Counted Feather 1/10,000 pounds	Feather Number	Counted Feather Weight	Weight per Counted Feather 1/10,000 pounds
Mean	5691	0.299	.525	5874	0.374	.637
1.	6051	0.306	.506	5693	0.337	.592
2.	5753	0.318	.553	5953	0.348	.585
3.	5617	0.289	.514	6169	0.384	.622
4.	5343	0.284	.532	6066	0.410	.676
5.				5489	0.390	.711

Table V, continued

White Wyandotte	Feather Number	Counted Feather Weight	Weight per Counted Feather 1/10,000 pounds
Mean	5988	0.408	.681
1.	6234	0.417	.669
2.	6379	0.419	.657
3.	5623	0.381	.678
4.	5830	0.406	.696
5.	5872	0.417	.710

Barred Plymouth Rock	Feather Number	Counted Feather Weight	Weight per Counted Feather 1/100,000 pounds
Mean	5550	0.359	.647
1.	5678	0.353	.622
2.	5623	0.373	.663
3.	5621	0.368	.656
4.	5483	0.368	.671
5.	5345	0.333	.623

White Plymouth Rocks	Feather Number	Counted Feather Weight	Weight per Counted Feather 1/10,000 pounds
Mean	5578	0.411	.737
1.	5524	0.410	.742
2.	5809	0.417	.718
3.	5170	0.401	.776
4.	6022	0.401	.666
5.	5368	0.426	.794

largest feather number. Their sister variety, as well as the Cornish, showed this same relationship.

Since a highly significant correlation has been found between body weight and counted feather weight, it is logical to expect that with increased body weight, there should be a corresponding increase in feather weight. Table VI clearly substantiates this assumption. With increased body weight there is a corresponding increase in counted feather weight.

Table VI

Mean Body Weight, Weight of Counted Feathers and Weight Per Counted Feather

Variety	Mean Body Weight	Mean Weight of Counted Feathers pounds	Mean Weight per Counted Feather 1/10,000 pounds
Dark Cornish Bantam	3.38	0.125	.256
Dark Cornish	6.55	0.229	.400
Crossbred	6.73	0.299	.525
Rhode Island Red	8.13	0.374	.637
Wyandotte	6.74	0.408	.681
Barred Plymouth Rock	7.65	0.359	.647
White Plymouth Rock	8.20	0.411	.737

Varieties with a similar feather type are placed together. Clearly the relationships between them can be seen. As body weight increased, the counted feather weight also increased. The only breed to interrupt this progress was the Wyandottes. The mean weight per counted feather likewise increased with body weight. This is the only table in which the related factor suggest such a high degree of symmetry.

By comparing the mean weights per counted feather, a definite relationship exists between the varieties; Cornish, Crossbreds and Reds. The feather weight of the Crossbreds is intermediate between that of their parents. As in other crossbreeding studies, the progeny characteristics are a blending of the parental phenotype. The feather weight of the Barred Rocks was slightly larger than that of the Reds. However, it was much lower than the weight of their sister variety. The largest weight per counted feather was found on the Wyandottes. The Bantams again had the smallest weight. As with the mean counted feather weight when the Cornish body weight is reduced by half (Bantams) the weight of a single feather is reduced approximately the same.

The mean weights per counted feather agrees with the visual differences found between varieties. From casual observation, feathers of the Cornish differ from other varieties. They are smaller and more compact than the large, loose, fluffy feathers found on a Wyandotte. Cornish feathers are also smaller than the less fluffy type found in the Plymouth Rocks and Reds. Due to the Red male parent, the feathers of the Crossbred are larger (weight) than those found on their Cornish Dam.

An analysis of covariance was made to see whether feather weight is dependent upon feather number. Because of the extreme ranges in feather number between the Bantams and Wyandottes, it was necessary to adjust feather number to a common mean. After feather number was adjusted, there was still a highly significant difference in the counted feather weight between these varieties. There is more variation in counted feather weight between the varieties than there is between the individuals making up these varieties. A highly significant correlation was found between feather number and feather weight. This correlation coefficient was .640.

For the feather number and feather weight correlation within varieties, a value of .142 was found. Due to this low correlation, a nonsignificant difference in the counted feather weight exists between the individuals within each of these varieties. The covariance data of feather number and feather weight are given in Table VII.

Since a highly significant correlation was found between feather number and feather weight, the Wyandotte's large feather weight may be accounted for because they had the highest mean feather number. Due to the same reasoning, the small feather weight of the Bantams may likewise be accounted for.

Relationship Between Feather Size and Body Weight

Two measurements (maximum length and width) were recorded on the first primary, first secondary and fourth tail feathers (all from the right side) of 34 individuals. For comparative purposes and to secure a comparable unit of measure for the analysis of variance, length and width were used. Of course, this figure is not the actual feather area because the maximum length and width were used as a basis for figuring. If this was true, each feather would be rectangular in nature with sides equal to the recorded length and width. This is not true because the feather increases from the base of the web to a maximum width and then tapers more or less to a point. Actually then this figure is not the true feather area, but for lack of adequate terminology, this calculated figure is used as a measure of feather size. Since the measurements were made in inches, this measure of feather size is presented as square inches. Because this same method was used for each of the three feathers from all birds, feather size from one individual to the next, as well as from variety to variety, should be comparable.

In comparison there is not a great deal of difference between the

Table VII

Analysis of Covariance of Feather Number (Y) and and Counted (W) Feather Weight

Source of Variation	Degrees of Freedom	Sums of Squares and Products			Error of Estimate			Correlation Coefficient
		SY^2	SYW	SW^2	Sum of Squares	Degrees of Freedom	Mean Square	
Total	33	6,042,096.95	922.248	0.343	0.20200	32		.64063**
Between Varieties	6	3,827,859.35	902.269	0.334	0.19318	6	.032196	
Within Varieties	27	2,214,237.60	19.979	0.009	0.00882	26	.000339	.14153

**highly significant

outlines of a primary and secondary feather. Considering the maximum measurements, the former is longer and generally narrower, while the secondary feather is shorter and broader. While superimposing a primary feather over the latter, it would cover the smaller length of the secondary, although it would fail to do so in the case of width. In relation, the smallest length and the greatest width was found in the tail feathers.

In only three minor exceptions, the mean size of the primary feather was larger than that of the secondary feather. These exceptions were found in the Bantams, Wyandottes and the Barred Rocks. In the former variety, the mean size of the secondary feather was 0.07 sq. in. larger. A slightly larger difference was present in the Wyandottes. The secondary feather size of the Barred Rocks was 0.44 sq. in. larger than the corresponding primary. Thereafter, all the mean primary feather sizes were larger than those of the secondaries. Notwithstanding the above exceptions, there was a gradual decrease in feather size from the primary through the secondary to the tail feather in all but one breed. In the Cornish, the size of the tail feather was larger than that of the secondary and almost equal to the size found in the primary feather. There was no evidence in the data for this difference.

Feather number varies with the 0.2 power of body weight (Hutt and Ball, 1938). If it is characteristic for each variety to have a definite number of feathers and since feather weight varies directly with body weight (Brody, 1938), the differences between individual feather counts would be due to the size of individual feathers. This tendency may be observed in Table VIII.

Table VIII

Mean Primary, Secondary and Tail Feather
Sizes for Each Variety

Variety	Mean Primary Feather Size inches	Mean Secondary Feather Size inches	Mean Tail Feather Size inches
Dark Cornish Bantam	7.27	7.34	5.61
Dark Cornish	10.32	9.86	10.08
Crossbred	11.21	11.10	11.08
Rhode Island Red	12.65	12.26	11.86
Wyandotte	12.32	12.41	11.22
Barred Plymouth Rock	12.48	12.26	12.07
White Plymouth Rock	12.28	12.07	11.61

The following square inches are necessary between the mean feather sizes of these varieties to be significant and highly significant.

Difference	Level	Primary	Secondary	Tail
Significant	5%	0.92 sq. in.	1.09 sq. in.	1.72 sq. in.
Highly Significant	1%	1.25 sq. in.	1.47 sq. in.	2.32 sq. in.

It was desirable to see if the observed differences in the size of the 3 feathers between the varieties and between individuals within the varieties were significant. These data are given in Table X. The computed data on the analysis of variance of the 3 feathers are included in the following table.

Table IX

Analysis of Variance on Size of Primary, Secondary and Tail Feathers

Source of Variation	Degrees of Freedom	Mean Square of Primary Feather	Secondary Feather	Tail Feather
Total	33			
Between Varieties	6	18.20**	18.39**	25.28**
Within Varieties	27	.51	.71	1.76

**highly significant

Table X

Mean and Individual Primary, Secondary and Tail
Feather Sizes of Each Variety

		Dark Cornish Bantam				Dark Cornish			
		Body Weight pounds	Primary Feather Size inches	Secondary Feather Size inches	Tail Feather Size inches	Body Weight pounds	Primary Feather Size inches	Secondary Feather Size inches	Tail Feather Size inches
Mean		3.38	7.27	7.34	5.61	6.55	10.32	9.86	10.08
	1.	3.26	8.64	7.90	5.69	6.71	10.95	10.00	8.91
	2.	3.33	7.54	7.91	4.67	6.80	9.58	9.97	11.47
Bird	3.	3.35	5.94	6.81	5.52	6.32	10.01	10.00	9.71
	4.	3.11	7.25	7.15	6.56	6.92	10.51	9.75	8.84
	5.	3.83	6.96	6.94	5.63	5.98	10.57	9.60	11.47

		Crossbred				Rhode Island Red			
		Body Weight pounds	Primary Feather Size inches	Secondary Feather Size inches	Tail Feather Size inches	Body Weight pounds	Primary Feather Size inches	Secondary Feather Size inches	Tail Feather Size inches
Mean		6.73	11.21	11.10	11.08	8.13	12.65	12.26	11.86
	1.	7.40	9.59	9.45	11.71	7.86	12.30	12.32	11.73
	2.	6.39	11.17	10.64	10.27	7.75	13.17	11.96	11.90
Bird	3.	7.13	11.63	12.51	10.64	9.09	12.88	12.13	10.64
	4.	6.00	12.46	11.81	11.70	7.92	12.30	12.79	11.81
						8.05	12.60	13.12	13.20

Table X, continued

	White Wyandotte				Barred Plymouth Rock			
	Body Weight pounds	Primary Feather Size inches	Secondary Feather Size inches	Tail Feather Size inches	Body Weight pounds	Primary Feather Size inches	Secondary Feather Size inches	Tail Feather Size inches
Mean	6.74	12.32	12.41	11.22	7.65	12.48	12.92	12.07
1.	6.64	13.20	9.79	11.81	8.00	11.09	13.30	12.40
2.	7.25	12.16	11.55	10.62	8.02	10.23	10.93	12.37
3.	6.95	12.70	12.32	11.30	7.38	12.00	14.23	7.61
4.	6.48	11.32	11.96	11.05	7.11	11.76	13.23	11.55
5.	6.40	12.24	11.44	11.30	7.75	12.32	12.95	16.40

	White Plymouth Rock			
	Body Weight pounds	Primary Feather Size inches	Secondary Feather Size inches	Tail Feather Size inches
Mean	8.20	12.28	12.17	11.61
1.	7.70	12.90	12.63	11.60
2.	7.75	13.13	12.48	12.16
3.	8.60	10.35	11.20	10.39
4.	7.43	12.45	12.79	10.96
5.	9.50	12.56	11.76	12.92

Briefly, the analysis of variance showed the following: There was more variation in feather size between the means of these varieties than there was between individuals within varieties. These differences are highly significant.

Due to the large differences in primary feather area between the Bantams and the 6 larger varieties, there was a highly significant difference between their means. With a similar feather size, the difference between the means of the Cornish and Crossbreds is on the borderline of significance. With the feather size of the four remaining larger varieties increasing, there was a highly significant difference between their means when compared with that of the Cornish. The mean feather size of the Crossbreds was smaller than either that of the White Rocks or Wyandottes. This difference is significant. Since the primary feather size of the Barred Rocks and Reds was larger than that of the Crossbreds, a highly significant difference is found between their means. The small differences between the mean feather sizes of the White Rocks, Wyandottes, Barred Rocks and Reds are nonsignificant.

The size of the secondary wing feathers is more variable than that of the primaries, as a result differences between them must be greater to be significant. Practically the same differences (nonsignificant, significant and highly significant) found between the variety primary feather means are again found between the variety means of the secondary feather. The difference between the secondary feather means of the Crossbreds and White Rocks is nonsignificant. Between their primary feather size means, this difference was significant. The difference between the mean sizes of the primary feathers in the Crossbreds and Reds is highly significant. Differences between the means of their secondary feathers are only significant.

The size of the tail feathers is even more variable. Still greater differences are required to give tests of significance. Like the primary and secondary feathers, there was a highly significant difference between the mean tail feather sizes of the Bantams and the 6 larger varieties. Very little difference was noted between the mean size of the tail feathers in the 6 large varieties. This was an outstanding difference when compared with the sizes of the two former feathers. With little range between their mean tail feather sizes, the Cornish, Cross-bred, Wyandottes and White Rocks showed a nonsignificant difference. The mean size of the tail feathers of the Reds and Barred Rocks was larger than that of the Cornish. This difference is significant. Due to similar feather sizes, all other differences between varieties are nonsignificant.

A single analysis of covariance was made between each of these 3 feathers and body weight. As previously noted, because of the extreme ranges in variety body weights, it was necessary to adjust body size to a single mean. After removing the influence of weight, all feather size differences between varieties are still highly significant. There is more variation between the feather size means of varieties than between individuals within varieties. These data are given in Tables XI, XII and XIII.

Between body weight and the area of the primary feather, a correlation of .747 was found. From analysis of covariance on body weight and size of secondary feather, a correlation of .761 was found for all males. A correlation of .749 was found between body weight and tail feather size. Being similar, these three values are all highly significant.

Table XI

Analysis of Covariance of Body Weight (X) and Size of First Primary Feather (A)

Source of Variation	Degrees of Freedom	Sums of Squares and Products SX^2	SXA	SA^2	Error of Estimate Sum of Squares	Degrees of Freedom	Mean Square	Correlation Coefficient
Total	33	88.56	77.97	123.09	54.44	32.		.74684**
Between the Mean	6	78.32	66.37	109.20	53.56	6	8.93	
Within the Birds	27	10.34	11.60	13.89	0.88	26	.034	.96828**

**highly significant

Table XII

Analysis of Covariance of Body Weight (X) and Size of First Secondary Feather (B)

Source of Variation	Degrees of Freedom	Sums of Squares and Products SX^2	SXB	SB^2	Error of Estimate Sum of Squares	Degrees of Freedom	Mean Square	Correlation Coefficient
Total	33	88.56	81.53	129.46	46.68	32		.76147**
Between the Mean	6	78.22	90.12	110.35	34.71	6	5.785	
Within the Birds	27	10.34	-8.59	19.11	11.97	26	.469	-.61138

**highly significant

Table XIII

Analysis of Covariance of Body Weight (X) and Size of Fourth Tail Feather (C)

Source of Variation	Degrees of Freedom	Sums of Squares and Products SX^2	SXC	SC^2	Error of Estimate: Sum of Squares	Degrees of Freedom	Mean Square	Correlation Coefficient
Total		88.56	101.88	209.15	91.95	32		.74862**
Between the Mean		78.32	87.22	151.69	65.27	6	10.88	
Within the Birds		10.34	14.66	47.46	26.68	26	1.03	.66185**

**highly significant

Correlations between body weight and primary, secondary and tail feather sizes within varieties differed. Similarities between the 3 correlations are absent. An almost perfect correlation was found between body size and size of the primary feather within varieties. This correlation is .968. Such a value is certainly highly significant. The larger individuals within a variety tend to have the largest primary feathers. As body weight varies, primary feather size proportionally changes. This is true because a larger bird requires larger primary feathers to support flight.

Between body weight and size of secondary feather within varieties, a minus correlation was found. This value is -.611. The larger individuals in a variety, therefore tend to have smaller secondary wing feathers. In a smaller bird, the size of a secondary feather is larger. This would increase the total wing area supplementing the smaller size of the primary feathers. Thus, a smaller bird would have equal flying ability.

From the analysis of covariance of body weight and tail feather size within varieties, a highly significant value was obtained. This figure is .662. Such a value tends to offset the minus correlation found between body weight and size of primary feather size.

At this time, additional work on the factors affecting feather weight in domestic fowl will be included. These findings were secured independently of the present paper. Although secured later, this additional work clearly shows the effects of castration on feather weight in domestic fowl. Since these findings were secured in this manner, they will be introduced seperately from the above paper. However, some of the literature references have already been cited.

Effects of Castration on Feather Weight in Domestic Fowl

Systematic studies on the effects of castration in the cock *Gallus domesticus* are not numerous, although orchotomy has been practiced for some time. To most casual observers there seems to be no indication that castration has an appreciable effect upon the plumage of the capon. According to Domm (1939, p. 270), Sellheim in 1898, Goodale in 1913 and 1916, Zawadowsky in 1922, Finlay in 1925, and Benoit in 1929 reported a greater feather length for the capon, while Horowitz in 1931 and 1934 showed the feather weight of capons of the Polish Greenleg, which is a relatively small-bodied bird, to be 6.13 to 7.42 percent of body weight while the feather weight for cocks of the same breed was only 4.43 to 5.72 percent of body weight. Unless capon feathers are narrower, these investigations indicate that there is a difference in feather weight of cockerels and capons. Mitchell, Card and Hamilton (1926) found feather weight on growing White Plymouth Rock cockerels and capons to vary from 3.79 to 7.90 percent and 6.25 to 8.28 percent of the live body weight respectively.

The following method was devised to secure a comparable measure of feather weight in capons and cockerels. At 8 weeks of age, 50 Barred Rock cockerels and 50 capons of the same variety were separately yarded under similar methods of feeding and management. Upon reaching 24 weeks of age, on August 1, and thereafter on the first of each of the 5 following months, 10 capons and 10 cockerels were randomly selected for the determination of feather weight. These birds were cooped without feed for 18 hours, then weighed, killed, and plucked.

At the 24 and 29 weeks periods, the feather weight was obtained by dry picking all of the feathers and weighing them in a cotton bag.

For the remaining 3 periods the feather weight was obtained by subtracting the plucked body weight from that secured priod to plucking, which permitted the use of the slack scald method of plucking.

The following table lists the number of cockerels and capons observed, their mean live body weight, and mean feather weight at each of the respective killing ages.

Date 1940	Age in weeks	Kind	Number of individuals	Mean live body weight pounds	Mean feather weight pounds
Aug. 1	24	Cockerel	10	5.14	0.28
		Capon	10	5.40	0.36
Sept. 3	29	Cockerel	10	5.49	0.33
		Capon	10	5.64	0.43
Oct. 2	33	Cockerel	10	6.73	0.36
		Capon	10	6.89	0.52
Oct. 30	37	Cockerel	9	6.82	0.45
		Capon	9	7.11	0.51
Nov. 20	40	Cockerel	9	7.12	0.45
		Capon	9	7.24	0.55

The body weight of both cockerels and capons continued to increase at a highly significant rate throughout the period of observation. Differences between body weights of cocks and capons at any one age were statistically nonsignificant.

Likewise the feather weight showed a highly significant increase with age. Therefore, feather weight increased with body weight. By 24 weeks there was a highly significant difference in feather weight between capons and cocks. Thereafter, the feathers of capons always weighed more in each successive period. Castration, or removal of the gonads, caused an increase in the amount of feathers prior to 24 weeks of age. The capons reached their maximum feather weight between the 29th and 33rd weeks, whereas the cockerels reached their maximum feather weight between the 33rd and 37th weeks. At 40 weeks of age the mean feather weight represented 7.60 percent of body weight for the capons and 6.30 percent of body weight for the cockerels. These percentage figures are higher than those reported by Horowitz on his (probably mature) capons of a smaller breed.

SUMMARY

This study shows the relationship of feather number, feather weight and feather size to body weight of 34 mature males. All records were analyzed by the methods of analysis of variance and covariance. The following results were secured:

1. Feathers of body and those up to a point 1/3 of the measured neck length were counted and weighed. Total feather weight was also secured.

2. Total number of feathers found on one white Wyandotte female (5.63 pounds) was 9515.

3. Feather number is a breed characteristic of varieties. In varieties of normal size, the smallest mean feather number was found on the Dark Cornish Bantams. The White Wyandottes had the largest.

4. Mean feather number of two Plymouth Rock varieties were similar. Rhode Island Red male x Dark Cornish female Cross tended to approach feather number of Dark Cornish dam.

5. In four of the five varieties, March plucked individuals of similar body weight had the minimum feather number.

6. Feather number increases with the 0.163 power of body weight, as contrasted to feather weight which increases with the 1.256 power of when calculated by the method of least squares.

7. Feather weight up to a point 1/3 of the measured neck length equals 90 percent of the total feather weight.

8. No relation was found between feather weight and period of year at which birds were plucked.

9. Dark Cornish had a smaller weight per feather than other

larger varieties. Weight per feather of Rhode Island Red male x Dark Cornish female Cross was intermediate between that of their parents.

10. Within varieties of feather weight, feather number is related to visual plumage outline.

11. Correlation coefficient between feather number, weight and size to body weight were determined for all birds. Correlation of these factors within varieties were also secured.

Body Weight

	Feather Number	Feather Weight	Feather Weight and Number	Feather Size primary	Feather Size secondary	Feather Size tail
All Birds	.564	.839	.640	.747	.761	.749
Within Varieties	-.090	.108	.142	.968	-.611	.662

12. Later, while comparing Barred Plymouth Rock cockerels and capons, additional feather weight data was secured. Both groups reached this maximum feather weight prior to completion of general body growth.

13. Capons reached their maximum feather weight between the twenty-ninth and thirty-third weeks, whereas, the cockerels reached their maximum feather weight between the thirty-third and thirty-seventh weeks.

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