

SOME FACTORS AFFECTING EGG WEIGHT IN
DOMESTIC FOWLS.

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P A R T I.

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BY

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I N T R O D U C T I O N

More attention has been paid by investigators to the number of eggs laid than to their size. The increased appreciation of quality in eggs by the buying public has led to more attention being paid by breeders and producers to the improvement in the size of the eggs they produce. The known relation between egg weight and chick weight has forced breeders and hatcheries to be vitally concerned in the problem of how to maintain and improve egg size.

There are probably three principal considerations in connection with egg weight; first, the genetic factors, second, the factors other than genetic which really bring about or retard the realization of the inherited ability of the individual, and third, the economic considerations.

*The terms "egg size" and "egg weight", as used in this thesis are synonymous.

REVIEW OF LITERATURE.

VARIATION IN EGG WEIGHTS.

ATWOOD (1914) has shown that egg weight varies from month to month, reaching the maximum in the early spring. CURTIS ('14) observed an increase up to the end of the second year. HADLEY & CALDWELL (1920) reported that there was a tendency for hens laying large eggs at first to possess high mean egg weights, but not sufficiently so to use for prediction purposes. They also showed that the second year egg weights were greater than the first year, especially in hens laying small eggs in their first year.

ATWOOD (1927) observed that the first egg in every cycle is generally heaviest and is usually laid relatively early in the day. The eggs decrease in weight as the time of laying in the day advances, and with each succeeding egg in the clutch.

ATWOOD (1928) found in Leghorns a 7.36 per cent increase in average weight of eggs, the second year over the first. During the second year the eggs averaged heaviest in December and lightest in July. Maximum egg size was not reached until the third laying/

laying year.

ATWOOD & CLARK (1930) reported that in the second and third years of production the minimum egg weight occurs in the hot summer months (July) and the maximum weight during late fall and at the beginning of winter (November and December), that increased production is usually accompanied by a decreased mean egg weight, and that egg weight is a relatively stable character persisting from year to year. MARBLE & HALL (1931) report an increase of 5.82 per cent for the record-year egg weight over the first-year egg weight.

THOMPSON (1930) pointed out the extreme variations in egg weights in individual hens and the economic possibilities of building up the large egg factor by weighing eggs for two or three weeks in February and again in June and July, if all the eggs laid cannot be weighed.

HAYS (1929) has stated that in Rhode Island Reds a pullet must lay eggs averaging 52 grams (about $1\frac{3}{4}$ ozs.) for the month of November and 55 grams for December, to lay 56.7 grams (2 ozs.) eggs by March 1st. At the Charlottetown Experimental Station, Canada, TUNNEY (1930) noted that birds producing eggs having an average weight per dozen of 20.4 ounces or less during/

during the first 28 days of the contest rarely produced 200 eggs having an average weight during the contest year (51 weeks) of 24 ounces per dozen.

HAYS (1930 b) observed that maximum as well as standard egg weight appeared on the average during the fourth laying month.

JULL (1930), using the records of 21 White Leghorns, found that by weighing the eggs one day a week a very satisfactory estimate of average annual egg weight was obtained.

DUDLEY (1931a), reported a rapid increase in egg size from October to March and April, a decline in the following two months followed by an improvement at the end of the first laying year. In nutritional experiments, he recommends replication of pens to eliminate genetical egg size differences. DUDLEY (1931b), studied the records of 198 birds to find the relation between the average weight of eggs laid on four consecutive days in the middle of each of the twelve months and the annual egg weight, also the relation between eggs laid on Fridays and the average annual egg weight. The correlation was high in both cases and the discrepancy should be rarely greater than 2 drams or 3.54 grams. THOMPSON, PHILPOTT, & PAGE (1931), concluded that the weighing individually of/

of all the eggs produced during any of the months, March, April, or May, is a practical and reliable means of estimating the annual egg weight of a bird. MAW & MAW (1932) reported that birds whose first ten eggs average less than 47.50 grams are not likely to lay eggs of standard weight and that weighing the first ten eggs laid in the fifth month gives a reliable estimate of mean annual egg weight. GINN (1932), reported that by weighing the eggs laid on the first and fifteenth days of each month, or the first one thereafter, a practical criterion is obtained of the average annual egg size of the hen.

INHERITANCE.

HURST (1913) suggested that small eggs (below 2 ozs.) were dominant to the large egg (over 2 ozs.). HADLEY & CALDWELL (1920) stated size of egg is an individual characteristic of fowls and probably inherited.

BENJAMIN (1920) stated that his results indicated that small egg size in White Leghorns was dominant.

HURST (1921) stated definitely that small egg size was dominant, in both White Wyandottes and White Leghorns, to large egg size.

KOPEC/

KOPEC (1924) found evidence of small egg size being dominant in crosses involving the Polish Greenfoots.

ATWOOD (1926) stated that mere selection of dams for egg weight will not certify the production of daughters which will lay eggs of the desired weight. NEWMAN (1927) attributes the small egg size in some strains of English White Wyandottes to the Silver Hamburgh blood in them.

MENZIES (1927a) as a result of ten years of observations, reported failure to combine production of over 200 eggs per year and over 2 ounce eggs, that small eggs are dominant, and large egg hens are slow maturing, large, coarse, and loose feathered.

WATERS & WELDIN (1929), working with White Plymouth Rocks, studied the selection for large and small egg-weights over several consecutive generations. A small egg-weight line was easily established. Six years of breeding for large egg size gave only 80 per cent. of individuals averaging 2 ounces. They state that small eggs are recessive and large eggs are incompletely dominant. Both male and female have an equal influence in transmitting egg size and it is neither sex-linked nor sex-limited.

PLATT (1929) observed that the weight of egg/

egg was influenced to a greater extent by individuality than were either shell texture or firmness of white.

HAYS (1929) proposed a two-factor theory. A dominant gene (A) for small egg size (below 56.7 grams by March 1st.) behaves as epistatic to a dominant gene (B) for large egg size, that is, the presence of gene A modifies the action of gene B, but does not act as a simple Mendelian dominant as would be the case if the gene for large egg size was recessive. Since gene A is epistatic to gene B, both Ab and AB hens will lay small eggs and only BB or Bb individuals will lay large eggs.

HAYS (1930a) found linkage between gene B for large eggs and gene I for intensity, i.e., small clutch size, and that highly-intense layers also inherit small egg size. No linkage was found between egg size and high persistency of broodiness, and that the tendency for early maturing birds to lay small eggs was due largely to physiological factors. He reports (1931) that the application of methods based on this theory has produced improvement in egg size for the flock as a whole.

MARBLE (1931) concluded that large egg size cannot be obtained as a result of selection for a single/

single generation. He suggests it can be obtained only after selection of hatching eggs from large egg size families over a period of many years. There are some indications that the inheritance from the immediate dam is of about equal influence as the combined inheritance from both grand-dams or the four great grand-dams. MARBLE & HALL (1931) showed that, with careful selection, both the body weight and the egg weight increased simultaneously with the increase in number of eggs.

THE RELATION OF EGG WEIGHT TO EGG PRODUCTION.

JULL (1924b) reported that the number of eggs laid by Barred Rock pullets did not affect the size of eggs laid.

PARKHURST (1926) confirmed JULL'S report with White Leghorns that there was no significant correlation existing between the 365 day record and the mean egg weight for that period. PARKHURST (1927a) found no significant correlation between the number of eggs laid to March 1st. and the mean egg weight to March 1st.

HAYS (1929) reported indications that heavy winter laying was accompanied by small egg size.

ATWOOD & CLARK (1930) concluded that the genetic/

genetic factors for production and egg size were independent, and that the observed tendency for high egg production to be accompanied by a slight decrease in mean egg weight appears to be due to physiological factors.

THOMPSON (1930) found no relationship to exist between annual egg total and egg size. ASMUNDSON (1930) found that small egg weight is not necessarily associated with high production. KNOX (1930) stated that there was no definite evidence of correlation between small size of eggs and high production, but that there are indications that the more eggs a hen lays the greater is the probability of her laying small eggs. MARBLE (1931) found that high egg production influenced egg weight very little. DUDLEY (1931a) showed that the correlation between the number of eggs laid by a bird in any month and their average weight centres round zero.

RELATION OF EGG WEIGHT TO EARLY MATURITY.

LIPPINCOTT (1921) stated as a result of studies with White Leghorns that a progressive selection for early laying might result in reducing the size of the first eggs laid.

ATWOOD (1923) showed in White Leghorns that the/

the earlier the sexual maturity the smaller were the first eggs laid, but that no correlation existed between early sexual maturity and the mean first year egg-weight. JULL (1924b) showed in Barred Plymouth Rocks that the earlier the pullets laid the lower the mean egg weight of the first ten eggs, the longer is the time required for egg weight to reach its maximum, as well as the lower the mean egg weight of the total production. He found early maturity a more important factor than body weight. PARKHURST (1926) showed that in White Leghorns slow-maturing pullets lay larger eggs when they start to lay, to March 1st., and throughout the year, and the more a pullet weighs at the time it starts laying, the heavier the first ten eggs.

RHYNEHART (1929b) reported that May-hatched Laying Trials pullets produced 2.1 times more small eggs in one test and 1.4 times more in another test than respective lots hatched in May. ^{March?} HAYS (1930b) stated that in Rhode Island Reds both age at first egg and body weight at first egg were significantly correlated with mean egg weight to January 1st. ATWOOD & CLARK (1930) suggested the removal of the smaller pullets in the autumn would materially increase the average weight of eggs for the flock. MARBLE (1931) did not find early maturity to be an important factor in egg weight. CARVER & BAUCHER (1931) found a significant positive correlation/

correlation between maturity and weight of the first few eggs but not with the mean egg weight for the pullet year. CRAHAM (1931) found a decided correlation in Rhode Island Reds between weight of pullet at first egg and the average monthly egg weights throughout the year.

THE RELATION OF EGG SIZE TO BODY
WEIGHT AT MATURITY.

HADLEY & CALDWELL (1920) showed that with White Plymouth Rock hens, those possessing the greater body weight lay the larger eggs. ATWOOD (1923) observed that with pullets the mean weight of eggs increased concurrently with the increase in the weight of the birds. JULL (1924b) with Barred Rocks, and PARKHURST (1925) with Leghorns, showed that the greater the maximum weight of a pullet for the year, the heavier the mean egg weight for the year. ATWOOD (1926) observed that the egg weight seems to vary with the seasonal variation in body weight and that the heaviest birds in general lay the heaviest eggs. RHYNEHART (1929) showed the average proportion of second grade eggs is highest in the case of the lightest birds, and lowest in the case of the heaviest birds. He suggests that White Wyandotte pullets should weigh at least 5 pounds each at the time laying starts, and White Leghorns/

Leghorns 4 pounds. An analysis of the records of about 6000 birds reported in the Blue Book of the Canadian National Poultry Record Association for 1929 shows a direct correlation between the size of the bird and the size of eggs laid in Single Comb White Leghorns, Barred Plymouth Rocks, White Wyandottes, and Rhode Island Reds. As between the four breeds, the heavy breeds did not lay eggs of a size in proportion to the weights of the birds.

ATWOOD & CLARK (1930) found the coefficient of correlation between body weight and egg weight were significant in all cases, i.e. irrespective of age. During the pullet year, there was a significant correlation ($+0.996 = .013$) between the monthly weight of the birds and the monthly weight of the eggs.

WILLHAM (1930) found a close relationship between body weight and egg size in both Leghorns and Barred Rocks. MARBLE (1930) found 4.5 to 5 pounds the most efficient size for White Leghorns. Smaller-bodied birds produced smaller eggs and larger ones did not produce sufficiently larger eggs to justify a heavier maintenance. MARBLE (1931) concluded that body weight is of major importance in obtaining satisfactory egg weight and that the selection for body weight is the first step in improving egg weight. Ten different factors were studied. GRAHAM (1932) reported a positive and/
and/

and significant correlation in Barred Plymouth Rocks between egg weight and body weight in pullets during February to July inclusive.

RELATION OF NUTRITION TO EGG WEIGHT.

ATWOOD (1914) & MOORE (1916) found that a restricted ration would reduce egg size, and that a dry mash was valuable in maintaining egg size. From Moore's work, animal protein feeds were indicated to be superior to vegetable protein feeds for egg size, and sour skim milk was found of special value. KISTLER, CHARLES, & KNANDEL (1926) reported that the use of condensed and dried milk products increase the size of eggs as compared to meat scraps. ROEMER (1927) reported better egg-size from fishmeal and dried butter-milk than from vegetable protein foods such as dried yeast and maize extract. BUCKNER (1927) reported the restriction of the calcium carbonate intake caused smaller egg size. TAYLOR & MARTIN (1927) found no relation between egg weight and thickness of egg ^eshell. PARKHURST (1927b) reported as a result of six years of study that the size of eggs is influenced materially by the ration fed, that sour skim milk has a special value in producing eggs of large size, that a well-balanced ration gives larger eggs than a poorly-balanced one/

one, and that a vegetable protein food, peameal, either with or without minerals, did not bring about an increased egg size over the low protein check pen.

NEWMAN (1927) reported that pullets fed on maize lay a higher percentage of first grade eggs than those fed on wheat, that under-feeding usually results in small eggs, and that pullets fed on animal protein foods laid larger eggs than those fed on vegetable protein foods. Pullets given warm water laid larger eggs than those given cold water. ROBERTSON & BASKETT (1929) reported as a result of their experiments that weight of egg is mainly a function of the mineral constituents of the feed and that the kind of protein fed is not a factor.

PARKHURST & LOMAX (1930), as a result of a two-year study found that Decorticated Earthnut Meal was definitely less satisfactory than Fishmeal for egg size and somewhat inferior to Meat Meal and Extracted Soya Bean Meal. Meat Meal was not found superior to Extracted Soya Bean Meal for egg size.

MOLYNEUX (1930) reported a larger egg weight when green food was fed to both pellet and all-mash fed birds, and still larger egg weight when both green food and oyster shell were added to the ration. KEMPSTER

(1930) observed that hens fed rations which were not suitable for egg production laid eggs smaller in size.

Dried/

Dried buttermilk was best, ground soya beans poorest, and cottonseed meal, meat scraps, and tankage were intermediate in their influence on egg size.

ROBERTSON & BASKETT (1928) found the addition of two per cent. minerals to a cereal mash, when unlimited oyster shell was also fed, gave an increase in egg size in yearling Wyandottes. They did not find the addition of a protein-rich feed affected egg size.

PRENTICE (1930) reported a slight increase in egg size by adding minerals to a standard fish meal (10%) ration.

NEWMAN (1930) showed that a meat and bone meal of high (65%) protein content gave a higher percentage of standard eggs than fish meal (55.6%), or a meat and bone meal of low (32%) protein content. He also showed that the addition of a portion of moistened mash, or of sprouted grain to the ration in which dry mash was used increased the average egg size.

SUZII & HATANO (1930) report equally good egg weight from fishmeal, soya bean cake, and a combination of the two foods. MACDONALD & ORR (1930) report that inadequate mineral supply limits egg size and report equally good egg size from soya bean meal and fishmeal.

A report of an experiment conducted at Mt. Gravatt/

Gravatt, Brisbane, Queensland, states that "In both cases where maize was extensively used the proportion of the first grade eggs was greater than that from the wheat ration. There were also considerably fewer undersized eggs produced". GRAHAM (1932) found no relationship between various protein concentrates fed and the size of egg produced. The presence of cod liver oil in the diet caused a slight increase in egg weight from February to July.

MISCELLANEOUS FACTORS.

NEWMAN (1931a) observed that size of egg is affected by cold, dry winds and by hot dry weather. ROSS (1931) attributes decline in egg weight to inaccurate and insufficient weighing of eggs and undue appreciation of high records. NEWMAN (1931b) gives the use of artificial lights on late-hatched pullets, and under-nourishment on range, as a cause of small eggs.

THOMPSON, PHILPOTT & PAGE (1931) observed that artificial lighting lowers egg weight and also causes greater variability in egg weight.

PHYSIOLOGICAL/

PHYSIOLOGICAL FACTORS.

VOITELLIER (1924) stated that the factors determining the weight of an egg are (1) the calibre of the oviduct, (2) the initial size of the yolk, (3) the variable deposits of albumen, and (4) the variable deposits of lime salts. These factors were considered by him to be subject to the laws of heredity and modified almost daily by other factors.

JULL (1924a) reported albumen weight was more highly correlated to egg weight than is yolk weight, that yolk weight is more highly correlated with egg weight than is shell weight and that the independent variation of the parts of the egg is probably caused by underlying physiological processes.

JULL (1930) observed that rate of increase in both egg-weight and body-weight up to the time that maximum body-weight is attained are probably due to physiological factors.

GUTOWSKA (1930) administered the hormone of the anterior lobe of the pituitary orally to Polish Green Legs in their second year of laying. The treated birds laid eggs in February averaging in weight 57.3 grams as compared with 53.3 for the control, and in March, 56.6 grams as compared with 52.3 grams for the control. The maximum egg weight of the treated birds was 76.5 grams and of the untreated 63 grams.

The/

The total weight of the eggs from the treated birds was greater than for the untreated. The weight of the hens originally was about 1700 grams. At the end of the period of observation (January to July, 1930), the treated hens were heavier than the untreated.

GUTOWSKA (1931) working with May hatched White Leghorn pullets further reported that a positive increase in egg size and an increased percentage of albumen was obtained by feeding .5 to .8 gram doses of anterior lobe pituitary substance.

ASMUNDSON (1931b) found the weight of the egg positively correlated with the weight of each of the parts and indications that the amount of albumen secreted was to some extent dependent upon the size of the bird and also upon the size of the oviduct. He also observed that the secretory and muscular activities of the oviduct depend on different physiologic factors.

EGG WEIGHT AND HATCHABILITY.

DUNN (1922) found in White Leghorns that the eggs of an individual fowl above her mean egg weight hatched less well than those below, but did not consider it an important cause of variation of fowls in hatchability. JULL & HAYNES (1925) found that egg weight, where normal eggs are involved, has no bearing on hatching quality and that there is no significant correlation/

correlation between the mean weight of eggs laid by an individual bird and the proportion of her fertile eggs that hatch.

MENZIES (1927b) reported that $2\frac{3}{4}$ and 3 oz. eggs, with a few exceptions, hatch badly.

HIBBERT (1930) reported that in South Africa a lower hatchability resulted as a flock was bred up to lay eggs weighing $2\frac{1}{4}$ ounces. RICE (1930) observed that extremely large eggs were not as good for hatching as a slightly smaller size. GRAHAM (1932) found that within normal bounds the weight of egg has little or no effect on its hatchability.

RELATION OF EGG WEIGHT TO WEIGHT OF CHICK.

ATWOOD (1909) & McBRIDE (1915) indicate that chicks hatched from very small eggs are deficient in vitality. BENJAMIN (1920) & HALBERSLEBEN & MUSSEHL (1922) found that large eggs produced large chicks. JULL & QUINN (1924) found that the weight of chick correlated to weight of egg, irrespective of whether or not the eggs were from pullets or from yearlings, and found no relation between weight of eggs and the sex of chicks hatched from them. PARKHURST (1927) reported on the relation between the weight of 1563 White Leghorn chicks and the weight of the eggs from which they hatched, and found a very high correlation (0.688 ± 0.00848) existed. The influence of the weight/

weight of the eggs set on the weight of the chicks of both sexes was still apparent when the chicks were eight weeks old. The chicks from the largest eggs were largest. UPP (1928) found a similar relationship in Rhode Island Reds between egg weight and chick size but found little or no correlation between egg-weight and the chick-weight at two, four, or twelve weeks of age. Rate of growth was in most cases independent of egg size. HAYS & SANBORN (1930) found that weight differences in Rhode Island Red chicks hatched from large and small eggs persisted at four weeks, but had disappeared at the age of 21 weeks. GRAHAM (1932) found a positive and significant correlation between weight of egg set and the weight of the chick hatched from it.

C. NUTRITIONAL AND MANAGEMENT FACTORS IN
RELATION TO EGG WEIGHT.

INTRODUCTION.

The records of some of the experimental groups at the National Institute of Poultry Husbandry, Newport, Shropshire, England, have been analysed in order to study the effect of various methods of feeding and management on egg weight. Pullets were used at the start of the experiments. They were divided into equal groups with respect to body weight. Health, breeding, sexual maturity, and age were also considered. In experiments in which birds were carried on to their second year, selection was produced when numbers permitted. Unless otherwise stated, the management and feeding of the groups compared was as near uniform as possible, with the only variation the one involved in the comparisons. Accurate trapnest records were kept of all the birds in the experiments and all the eggs laid were weighed individually daily. Food consumption records were obtained by weekly weighings. All the birds were weighed at the beginning, completion, and periodically, during the experiments.

STATISTICAL ANALYSIS.

In making the tests for significant differences between the productions of the various pens in each experiment, use has been made of the analysis of Variance devised by Dr R. A. FISHER, F.R.S. of Rothamsted Experimental Station as applied by DUDLEY (1931a). In the tables, the abbreviations are:-

d/F Degrees of Freedom.

S of S. Sums of squares of deviations from the mean.

V. Variance.

s.d. Standard of Deviation.

Unrecorded eggs and dead birds have not been included.

EXPERIMENT NO. I. THE RELATION OF VITAMIN D DEFICIENCY TO EGG WEIGHT.

OBJECT: To find out if, and to what extent, a deficiency of the Antirachitic Vitamin in the ration would affect the weight of eggs produced on that ration.

PREVIOUS HISTORY. In 1927-1928, three pens of S. C. White Leghorns were compared. One pen was given free access to a grass run throughout the experiment; a second pen was confined to a house with an open front, and a third pen was confined behind ordinary glass. The third pen gave a lower egg weight, especially during/

during the April to June periods. The division of the pen and the addition to the ration of two per cent cod liver oil did not improve egg size. In 1928-1929, a similar experiment with White Wyandottes gave results in accord with those obtained the previous year. The differences were not significant, but the egg size was noticeably poorest in the confined pen during the period from May to July. During 1929-1930, cod liver oil and irradiated ergosterol were given on an equivalent basis and to two pens of White Wyandottes. The difference in egg size was not significant.

MATERIAL. During 1930-1931, six groups of S. C. White Leghorn pullets, all receiving the same basal ration which was deficient in Vitamin D. contextⁿ, were housed in different pens of the same house. Four pens had the usual type of front with hopper windows, while two other pens had a front with windows that could be adjusted so that part or all the front was open. Whenever weather permitted, the fronts of these two pens were opened in order to let the direct rays of the sun shine on to the birds. In one of these two pens, the entire front was glazed with Vita glass. The Vita glass used in this experiment had been installed at the time the experiment started.

RESULTS/

TABLE NO. I

VITAMIN D EXPERIMENTS.
EGG WEIGHTS (IN GRAMS) BY LUNAR MONTHS.

1930-1931 PULLETS.

PEN NO.		1	2	3	4	5	6
PERIOD NO.	LUNAR MONTHS.	COMMON GLASS.	COMMON GLASS C.L.O.	COMMON GLASS OSTELIN.	VITA GLASS.	ADJUSTABLE VITA GLASS.	FRONTS. COMMON GLASS.
1	Oct-Nov.	51.67	52.22	52.71	53.72	52.06	52.04
2	Nov-Dec.	53.89	54.59	54.02	55.81	54.12	53.97
3	Dec.	53.95	55.88	56.23	57.70	55.96	54.86
4	Dec-Jan.	54.00	56.79	56.24	58.56	54.09	52.71
5	Jan-Feb.	56.92	58.73	58.93	57.76	57.62	58.40
6	Feb-Mar.	57.23	59.95	60.02	58.79	59.46	57.40
7	Mar-Apr.	56.32	58.79	59.26	60.43	59.65	59.66
8	Apr-May.	55.70	57.01	57.03	58.94	56.27	55.62
9	May-Jun.	52.34	57.63	57.86	59.65	57.46	56.94
10	Jun-Jul.	52.80	58.40	58.98	59.62	57.60	56.93

DIFFERENCES/

RESULTS:-

White Leghorn pullets housed in Pen No.1 behind ordinary glass and not given an adequate amount of vitamin D gave a significantly lower average egg weight than the other pens in the experiment except Pen No. 3 the irradiated ergosterol pen. Pen No 3, the ergosterol pen, had an average egg weight that was significantly lower than that of Pen No 2, the Cod liver oil pen, but not that of the other pens. The pens and their average egg weights were as follows:-

PEN	GRAMS	DRAMS	NO. of Birds at end of experiment
No.1. Common glass	54.52	30.89	21
" 2. Common glass and Cod Liver Oil	57.13	32.33	25
" 3. Common glass and irradiated Ergos- terol (Ostelin)	56.60	31.91	18
" 4. Vita glass	58.57	33.15	24
" 5. Adjustable front with Vita glass	56.78	32.08	22
" 6. Adjustable front with common glass	56.48	32.14	23
		TOTAL	<u>133</u>

TABLE NO. I. gives the average monthly egg weights for the experiment and Chart No.I. shows graphically the/
the/

the monthly egg weights for the common glass (No.1.) and common glass (No.2) pens. The statistical analysis follows:-

	DEGREES of FREEDOM	SUM of SQUARES	VARIANCE
(a) Within pens	126	467.7640	3.7124
(b) Between pens	5	58.9523	11.7905
TOTAL	131	526.7163	

The analysis of variance shows that the variance between pens (b) is greater than between birds of the same pens (a). To test the significance of the divergence, the value of Z is found out together with the value for Z corresponding with $P = .05$. They are found to be as follows:-

	VALUE of Z	VALUE of Z corresponding with $P = .05$
Pens 1 - 6	.5778	< .7817

The divergence is, therefore, significant. Taking 3.7124 as the variance of the average egg weights of birds in a pen, the following standard errors have been worked out for the differences stated.

<u>DIFFERENCES BETWEEN PENS</u>	<u>MAGNITUDE OF DIFFERENCE</u>	<u>S.E. OF DIFFERENCE.</u>
1 and 3 -----	1.02 -----	.62
1 and 5 -----	1.19 -----	.59
1 and 6 -----	1.25 -----	.58
1 and 2 -----	1.44 -----	.57
1 and 4 -----	2.26 -----	.58
4 and 3 -----	1.24 -----	.60
4 and 5 -----	1.07 -----	.57
4 and 6 -----	1.01 -----	.56
4 and 2 -----	0.82 -----	.55

The average egg weight of Pen No. 1 is, therefore, significantly lower than all others with the exception of Pen No. 3, and the average for Pen No. 3 is significantly lower than that for Pen No. 2.

The Relation of Vitamin 'D' Deficiency to Egg-Weight in 1930-31 S.C. White Leghorn Pallets.

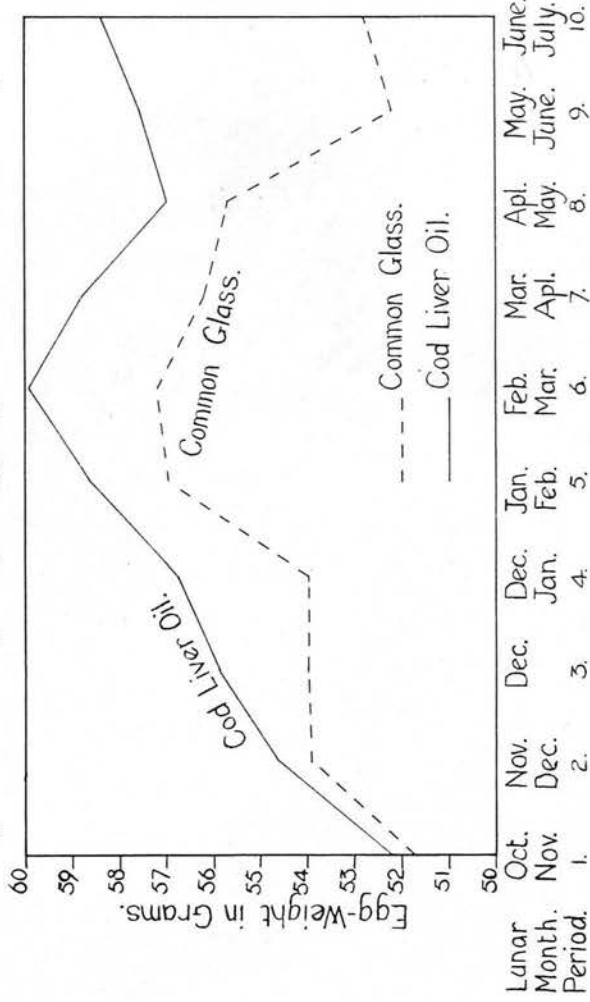


FIG. NO. I The Monthly egg weights of the Common Glass Pen as compared with those of the Common Glass Pen plus Cod Liver Oil.

EXPERIMENT NO. II. THE INFLUENCE OF ARTIFICIAL
ILLUMINATION ON EGG WEIGHT.

OBJECT.

To obtain information on the relation of artificial lighting and different systems of inducing extra food consumption during the winter months to egg weight.

PREVIOUS HISTORY.

An experiment with late hatched Single Comb White Leghorn pullets was carried on from September 30th, 1927, to August 31st, 1928 at the National Institute of Poultry Husbandry, Newport, Shropshire. Two pens were used, one of which was lighted by means of the "Morning Lights" System. There was no difference in the egg size in the two pens. It was very poor in both.

MATERIAL.

From September 2nd, 1930 to August 3rd, 1931, six groups of April hatched Single Comb White Leghorn pullets were used to compare different systems of inducing extra food consumption during the winter months. Each pen was the same size and similar in equipment except for the arrangement for lights. Each pen had a run about 20' x 120' in size to which they had access/

access to October 14th and after April 1st. They were confined to the house between these dates.

The variations in the methods of lighting and feeding were as follows:-

- PEN NO. 1. "Evening Lunch" System. The lights were switched on at 9 p.m., dimmed at 9.45 and out at 10 p.m.
- PEN NO. 2. "Morning" lights. The lights were switched on at 7 a.m. and off as soon as it was light enough for the fowls to see to eat.
- PEN NO. 3. "Morning and Evening" lights. At 5 a.m., the lights were automatically switched on, at day-break were switched off, at dusk were switched on again, were dimmed at 6.45 and were switched off at 7 p.m. This arrangement gave a fourteen-hour day.
- PEN NO. 4. "Special Mash". This pen received a more highly concentrated mash which, with a low food consumption when no lights were given, would enable a larger amount of digestible protein to be assimilated.
- PEN NO. 5. Had a dim light (20 Watts) burning all night.

PEN/

PEN NO. 6 was the control pen with a standard ration and no lights.

The lights came on gradually from October 7th to 17th, 1930 and were gradually discontinued from March 25th to April 1st. All-in-one rations were given with no gut, oyster shell or green food available. Pens 1, 2, 3, 5, and 6 received little standard mash and pen 4 a special mash. The mashes were as follows:-

INGREDIENTS.	PARTS BY WEIGHT.	
	Standard Mash	Special Mash
Maize Meal	49	50
Thirds	14	14
Bran	7	0
Alfalfa Meal	8	8
Ex. Soya Bean Meal	5	7
Dried Skim Milk	5	7
Meat and Bone Meal	5	7
Med. Cod Liver Oil	1	1
Ground Limestone	3	3
Sterilised Bone Flour	2	2
Common Salt	1	1
TOTAL	100	100

RESULTS.

There was no significant difference between the egg weights in any of the pens. The special higher/

higher protein mash pen gave the highest average egg weight, but the difference cannot be considered to be significant. The egg weights for the various pens in grams and the number of birds at the end of the experiment were as follows:-

PEN NO.	MANAGEMENT.	AVERAGE DRAMS	EGG WEIGHT. GRAMS	NO. OF BIRDS AT END OF EXPERIMENT
1	Evening Lunch	31.38	55.60	31
2	Morning Lights	31.51	55.83	36
3	14-hour Day	31.24	55.36	31
4	Special Mash	31.93	56.62	29
5	All Night Lights	31.57	55.94	35
6	No Lights	31.43	55.69	30
TOTAL				192

The statistical analysis is as follows:-

PENS 1-6	DEGREES OF FREEDOM	SUMS OF SQUARES	VARIANCE
Within Pens	186	702.3020	3.7758
Between Pens	5	8.3398	1.6680
	191	710.6418	

As/

THE INFLUENCE of LIGHTING on EGG-WEIGHT IN
1930-31 S.C. WHITE LEGHORN PULLETS.

FIG. II.

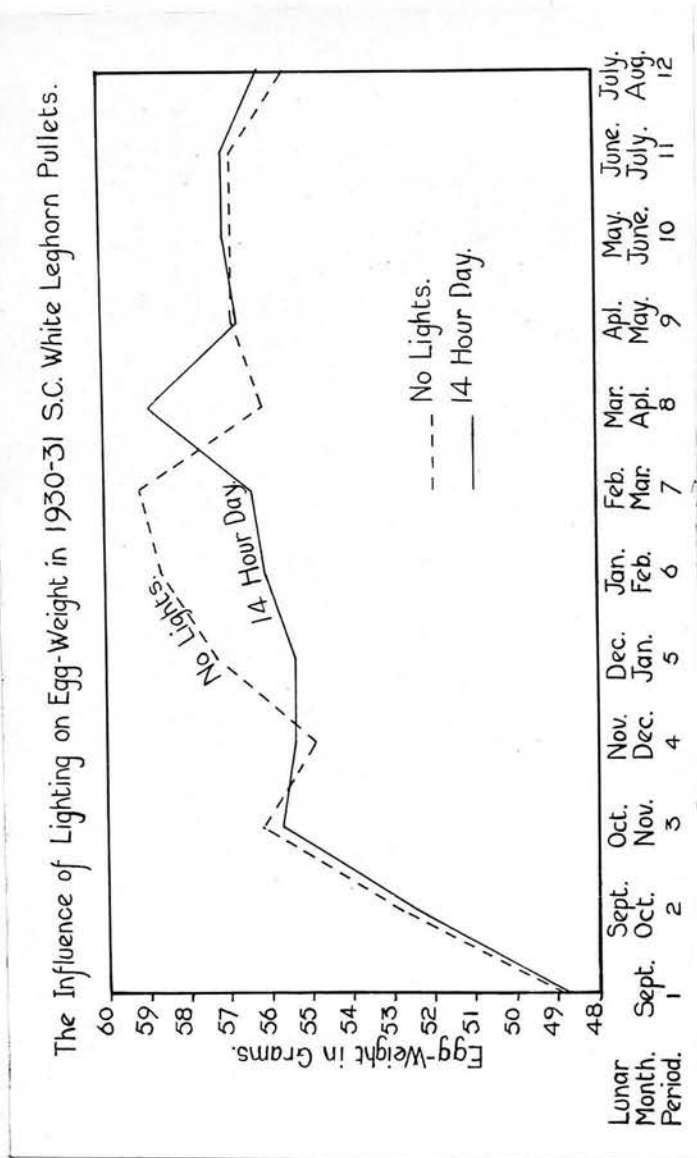


FIG. II. The monthly egg-weights of S.C. White Leghorn Pullets in the 14 Hour Day Pen as compared with those of the No-Lights Pen, 1930-1931.

As the variance between pens is smaller than the variance within pens, it can be concluded that the average egg weights of the various pens in the experiment do not differ significantly from one another.

As the best egg production was obtained from the 14-hour day pen and the egg size was slightly lower in that pen, a study was made of the monthly egg weights in relation to the monthly egg production in this and the unlighted pen. FIGURE NO. II shows graphically the monthly mean egg weights of the two pens. The monthly production and egg weight figures are given in TABLE NO. 2. Although both pens reached standard egg size, at about the same time, further increase in egg size was much slower in the lighted pen and appeared to be due to the much higher winter egg production in the lighted pen as compared to the unlighted pen. The correlation between egg production and egg weights was not, however, significant at any time during the experiment.

TABLE NO. II./

EXPERIMENT NO. III. THE COMPARISON OF THE EFFECT
ON EGG WEIGHT OF ALL-MASH AND PELLET RATIONS.

OBJECT.

To compare the effect upon egg weight of an all-mash ration, with and without supplements, with the same ration in pellet form, with and without supplements.

MATERIAL.

The experiment started on August 16th, 1929 and the pullet year ended on July 18th 1930. Some of these birds were carried on in two pens for another 48 week period to July 16th, 1931. Another group of pullets were started on September 12th, 1930. S.C. White Leghorns were used and supplements were given only during the first experimental period.

FIRST GROUP 1929-1930.

Two hundred and ten pullets hatched on February 15th and March 1st 1929 were divided into six pens of 35 birds each. They had been reared on all-mash starter and growers rations and were housed in similar pens. Except in the case of green food and oyster shell, the rations fed to the six pens were exactly the same throughout the experiment, the only difference being in the fact that three pens of birds received/

received their rations in pellet form and that these pellets had an addition of whey paste in the early part of the experiment which was later on altered to $2\frac{1}{2}\%$ of whey paste and, or, $2\frac{1}{2}\%$ of molasses. Otherwise there was no difference in the laying rations which consisted of the following parts by weight:-

Yellow Maize Meal	49
Wheat Bran	14
Thirds	14
Meat and Bone Meal	6
Dried Skim Milk	6
Extracted Soya Bean Meal	6
Salt	1
Medicinal Cod Liver Oil	2
Ground Limestone	2

Similar quantities of Pellets and All-mash were purchased at the same time from the same food merchants and held for the same period. Pens 1, 2, and 3 received the all-mash ration and pens 4, 5, and 6 received the pellets. Pen No. 1, the control pen, received the all-mash ration with no oyster shell and no green food. Pen No. 2 received the same ration with the addition of two pounds of green food per 35 birds per day. Pen No. 3 received the same ration with the addition of green food as in pen No. 2. plus oyster/

oyster shell ad. lib., fed in open hoppers. Pen No.4 received the ration in pellet form and no oyster shell and no green food and is directly comparable to Pen No. 1. Pen No.5 received pellets and green food, as in Pen No.2, and Pen No.6 received pellets and both green food and oyster shell, as in Pen No.3. The birds had ample fresh water but no grit was fed. The pullets were confined from the beginning of the experiment (August 16th 1929) until March 14th and then had access to grass runs. The birds received artificial illumination by the "Morning and Evening Lights" System during the winter months. Mash and pellets were always available to the birds and fresh food was added daily at 4 p.m.

SECOND GROUP 1930 1931.

67 of the birds from the first group were divided between two pens on the basis of their first year records. Pen A1 was made up of birds selected from the all-mash pens Nos. 1, 2, and 3 and Pen A2 from the pellet pens Nos. 4, 5, and 6. Both groups A1 and A2 had similar pens and access to similar grass runs throughout the experimental period. Pen A1 received the Institute All-Mash breeders ration, which is as follows, all parts being by weight:-

Maize Meal	48
Wheat Bran	9
Thirds/	

Thirds	15
Dried Skim Milk	6
Meat and Bone Meal	6
Common Salt	1
Cod Liver Oil	2
Ground Limestone	3
Steamed Bone Flour	2
Alfalfa Meal	8

Pen A2 received the same mash in pellet form.

THIRD GROUP 1930 1931

The all-mash group, Pen F7, contained 40 pullets hatched on March 29th, 1930 and fed from hatching on all-mash rations. The pellet group, Pen F8, contained 40 pullets hatched at the same time and reared on the same rations from hatching as Pen F7, only in pellet form. Pen F7 received the following ration, all parts being by weight:-

Maize Meal	49
Wheat Bran	7
Thirds	14
Extracted Soya Bean Meal	5
Dried Skim Milk	5
Meat and Bone Meal	5
Common Salt	1
Cod Liver Oil	1
Ground Limestone	3
Steamed/	

Steamed Bone Flour 2

Alfalfa Meal 8

Pen F8 received the same ration, with about 5 per cent of whey paste, in pellet form. No green food, grit, or oyster shell was fed. An ample supply of fresh water was available at all times. The birds were confined from October 15th to April 24th after which time they had access to grass runs. During the winter months, the birds received artificial illumination by means of the "Evening Lunch" System. After April 24th the ration was changed to the ration given to the first group during 1929-30.

RESULTS/

RESULTS.. FIRST GROUP 1929-1930.

The average egg weights and the number of birds at the end of the experiment are given for the first group in TABLE NO. III.

TABLE NO. III. INFLUENCE ON EGG SIZE OF PELLETS AND ALL-MASH RATIONS WITH AND WITHOUT OYSTER SHELL AND GREEN FOOD. WHITE LEGHORN PULLETS.

PEN METHOD OF FEEDING	NO. OF BIRDS AT THE END OF EXPERIMENT	AVERAGE EGG WEIGHT grms. grms.
1 All-mash, no oyster shell no green food.	33	55.48 31.35
2 All-mash, no oyster shell + green food	33	56.85 32.12
3 All-mash, + oyster shell + green food	33	57.35 32.40
4 Pellets, no oyster shell no green food	35	56.78 32.08
5 Pellets, no oyster shell + green food	30	56.88 32.14
6 Pellets, + oyster shell + green food	34	57.24 32.34
TOTAL	198	
1, 2, and 3 combined all-mash pens	99	56.54 31.97
4, 5, and 6 combined pellet pens	99	56.93 32.19
TOTAL	198	

The/

The control Pen, Pen No.1, gave a significantly smaller egg size than the pen getting the same ration supplemented with green food and no oyster shell, (Pen No.2) and the pen getting the same ration supplemented by green food and unlimited oyster shell (Pen No.3). The pen getting the same ration in pellet form (Pen No.4) gave smaller, but not significantly smaller, egg size than the pen getting the same ration supplemented by green food with oyster shell (Pen No.5) and the same ration supplemented by both green food and oyster shell (Pen No.6). The largest egg size was obtained when both green food and oyster shell were given. When the all-mash pens are combined and compared with the combined pellet pens, the egg weight is significantly greater in the pellet pens.

SECOND GROUP 1930-1931 YEARLINGS.

The egg size in the second group was significantly greater in the pellet pen than in the all-mash pen. In the pellet pen, 61 birds completed the experimental year and the mean average egg weight was 62.04 grams (35.14 drams) for the pellet pen and in the all-mash pen the number of birds to finish was 50 and the average egg weight was 60.15 grams (33.86 drams). The analysis of variance is as follows:-

DEGREES/

	DEGREES OF FREEDOM	SUM OF VARIANCE SQUARES
Within Pens	109	451.5860 4.1430
Between Pens	1	44.5937 44.5937
	110	496.1797

As the variance is greater between pens than within pens it was necessary to calculate Z which was found to be 1.1881 as the value of Z corresponding with $P = .05$ was $<.7246$, the differences in egg weight are therefore, significant.

THIRD GROUP. 1930-1931 PULLETS.

The pellet pen of the third group completed the year with 29 birds and the average egg weight was 59.98 grams (32.38drams). The all-mash pen finished with 34 birds and an average egg weight of 55.65 grams (31.29drams). The analysis of Variance is as follows:-

	DEGREES OF FREEDOM	SUM OF VARIANCE SQUARES
Within Pens	61	247.5078 4.0575
Between Pens	1	18.5463 18.5463
TOTAL	62	266.0541

The/

The variance between pens being greater than within pens, the value of Z was calculated and found to be .7598 with the corresponding value for Z with $P=.05$, $<.7246$. The egg weight for the pellet pen is, therefore, again significantly greater than the egg weight for the mash pen. The monthly egg weights are given in TABLE NO.IV.

TABLE NO. IV.

MONTHLY EGG WEIGHTS. WHITE LEGHORN PULLETS 1930-1931.
PELLETS AND ALL MASH.

PERIOD NO.	1	2	3	4	5	6	7	8	9	10	11	12
LUNAR MONTHS.	Aug. Sep.	Sep. Oct.	Oct. Nov.	Nov. Dec.	Dec. Jan.	Jan. Feb.	Feb. Mar.	Mar. Apr.	Apr. May.	May. Jun.	Jun. Jul.	Jul. Aug.
PELLETS.	49.25	54.92	55.62	55.60	57.55	57.95	58.31	59.34	58.52	61.86	60.69	59.45
ALL MASH.	47.75	53.09	54.80	55.44	56.36	57.20	54.89	57.60	55.63	58.10	56.72	55.69

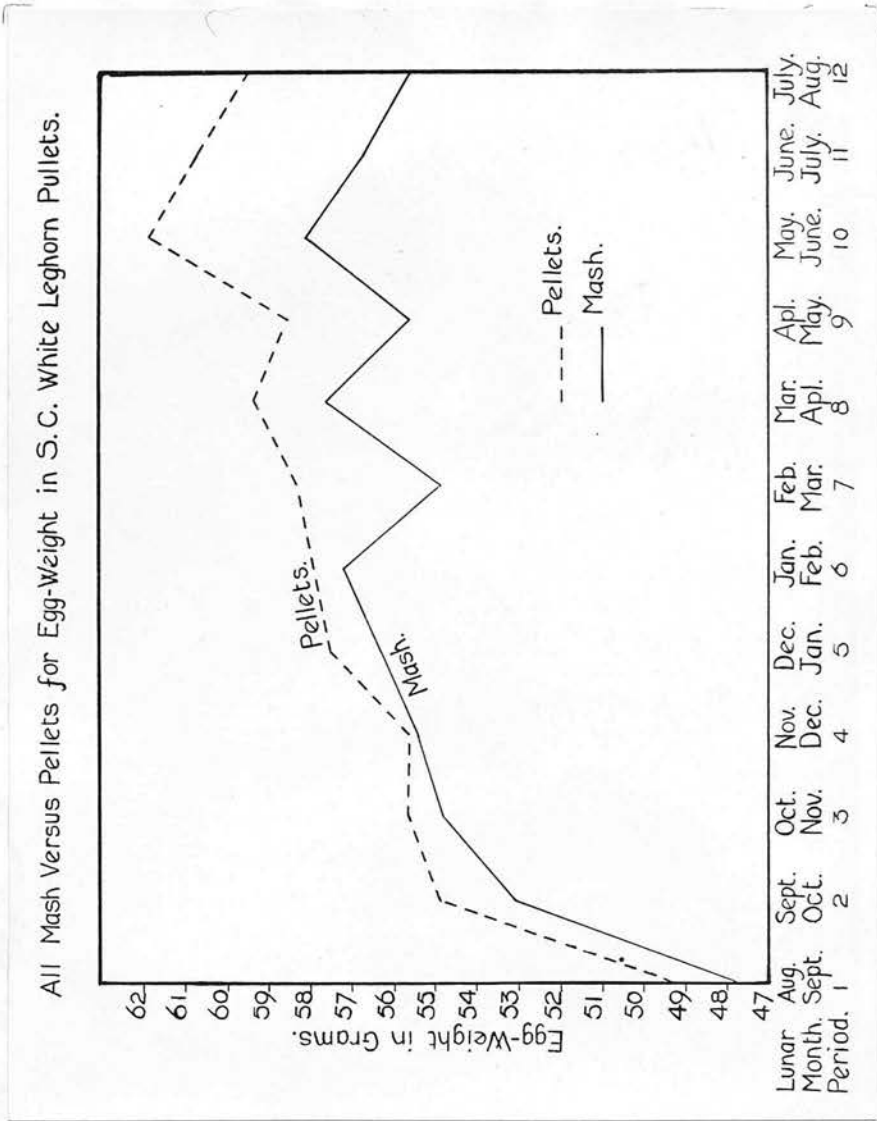


FIG. No. 3. Comparison of monthly egg weights for all mash and pellet pens of S.C. White Leghorn pullets, 1930-1931.

EXPERIMENT NO. IV. THE INFLUENCE OF VARIOUS
PROTEIN FOODS ON EGG WEIGHT.

OBJECT.

To find the relation of the kind of protein-rich food used in the ration with the size of eggs obtained.

PREVIOUS HISTORY.

The results of six years of experiments from 1920 to 1926 at the Idaho Agricultural Experiment Station (PARKHURST 1927) showed consistently and very definitely that sour skim milk was, under the conditions of the experiments, superior to other foods commonly used as a source of protein and that a well balanced ration gave larger eggs than a poorly balanced ration. The addition of peameal or peameal and a mineral mixture did not bring about an increase in egg size in comparison with a check pen in which there were no protein-rich foods. Meat meal and meat scraps were found to be of about equal value and slightly inferior to tankage in their influence on egg size. Condensed buttermilk, milk curd, dried buttermilk, and milk casein were apparently about equal and somewhat better than meat meal or meat scraps, while milk whey increased egg size only slightly over the check pen.

MATERIAL/

MATERIAL.

During 1927-1928 and 1928-1929, comparisons were made with S.C. White Leghorn pullets between four rations of comparable crude protein content, but with the source of protein different in each case and with proper mineral supplements supplied. The four protein sources were meat meal (60% protein) white fish meal (60% protein), extracted soya bean meal (45% protein), and decorticated extracted earth (pea) nut meal (45% protein).

Each pen consisted of forty birds at the start of the experiment. In both years, the pullets were hatched in April. The experimental pens were located in a long continuous laying house and were similar. The feeding and management was identical except in the details of the rations being compared. The fowls received the dry mash ad. lib. and a scratch food of two parts wheat, one part kibbled maize and one part oats. Oyster shell, granite grit and clean water were always available. The pens had free access to runs during 1927-1928 and were given a limited amount of green food during the winter months. The pens were confined throughout 1928-1929 and received kale at the rate of 5 pounds per 100 birds daily, and one per cent of medicinal cod liver oil was included in the scratch food, except for part of the winter, when/

When it was increased to two per cent. No lights were used. The composition of the mash rations were as follows, all parts being by weight:-

PEN NO.	DESIGNATION.	MAIZE MEAL.	WHEAT BRAN.	THIRDS.	MEAT MEAL.	FISH MEAL.	EX.SOYA BEAN MEAL.	DECORTI-CATED EARTH NUT MEAL.	MINERAL MIXTURE.
1	Meat Meal	112	56	112	28	-	-	-	-
2	Fish Meal	112	56	112	-	28	-	-	-
3.	Soya Bean Meal	112	56	112	-	-	46	-	10
4	Earth Nut Meal	112	56	112	-	-	-	42	10

The mineral mixture consisted of 55 per cent of steamed bone flour, 20 per cent of ground limestone, 20 per cent of common salt and 5 per cent of sulphur.

RESULTS .

TABLE NO.V. gives the average egg weights for each pen for each year and combined for two years.

TABLE NO.VI. gives the monthly average egg weights for 1928-1929 only.

EXPERIMENTAL TABLE /

TABLE No. V.

AVERAGE EGG WEIGHTS FOR EACH YEAR AND THE COMBINED AVERAGES.
VARIOUS PROTEIN FOODS COMPARED.

PEN No.	RATION	PULLETS 1927-1928		PULLETS 1928-1929		Combined average.	
		Grams	Drams	Grams	Drams	Grams	Drams
1	Meat meal	55.35	31.26	54.53	30.81	54.98	31.05
2	Fish meal	55.24	31.22	56.38	31.86	55.82	31.54
3	Soya bean meal	56.34	31.80	54.23	30.64	55.27	31.28
4	Earth nut meal	54.82	30.87	54.07	30.55	54.1	30.73

STATISTICAL ANALYSIS.

An analysis of the variance in the pens showed that the variance between pens was greater than within pens, and it was necessary to use the Z test.

There was no significant difference in the egg size for 1927-1928, but the eggs from the earth nut meal pen averaged lowest, the eggs never averaging to weigh two ounces during the year, while all the other pens reached standard weight by the fifth month (January-February). There was a drop in egg size in all pens during the ninth (May-June) period. During 1928-1929, a similar drop came in the eleventh (July-August) period. During the second year, the egg size in the fish meal pen was significantly better than in the earth nut meal, soya bean meal or meat meal pens. For the two years combined, the fish meal pen gave a significantly larger egg weight than the earth nut meal pen only.

TABLE No VI.

MONTHLY AVERAGE EGG WEIGHTS IN GRAMS. VARIOUS PROTEIN FOODS COMPARED. 1928-1929.

PEN No.	RATION	SEPT-OCT.	OCT-NOV.	NOV-DEC.	DEC-JAN.	JAN-FEB.	FEB-MARCH	MAR-APRIL	APRIL-MAY	MAY-JUNE.	JUNE-JULY.	JULY-AUGUST.	AUGUST.
1	Meat meal	48.92	50.91	52.01	54.10	56.09	57.35	57.09	56.51	55.21	54.83	53.74	54.36
2	Fish meal	50.39	51.93	53.71	55.88	57.99	57.77	57.87	57.44	56.80	57.93	56.66	57.65
3	Soya bean meal	48.00	50.03	52.24	54.67	55.96	56.68	56.23	55.66	54.85	55.01	53.60	54.57
4	Barth nut meal	49.45	51.00	51.92	53.16	55.76	56.70	56.44	55.62	54.37	55.98	53.01	53.38

EXPERIMENT NO.V. THE INFLUENCE OF A
MINERAL MIXTURE ON EGG WEIGHT.

OBJECT.

To find out if the addition of a Mineral Mixture to the mash of an accepted ration for egg production would improve the weight of the eggs produced.

PREVIOUS HISTORY.

The addition of a mineral mixture to the pea meal ration during the Idaho experiments (PARKHURST 1927) did not improve the egg weight of the pen as compared with the pea meal ration without a mineral mixture

MATERIAL.

During 1927- 1928 and 1928-1929, a comparison was made between the meat meal pen (EXPERIMENT NO.IV PEN NO.I) with about 3 per cent of a mineral mixture composed of 55 per cent steamed bone flour, 20 per cent ground limestone, 20 per cent common salt, and 5 per cent sulphur added to the mash. Oyster shell and grit were available to both pens and 5 pounds of kale per 100 birds was given daily.

RESULTS.

An analysis of variance showed there was no significant difference between the egg weights for the two pens. Both pens showed a drop in egg size during the May-June period. Pen No.1 averaged 55.35 grams (31.26 drams)/

(31.26 drams) for the year 1927-1928, and for 1928-1929 pen averaged 54.53 grams (30.81 drams). The mineral Pen No.2 averaged 56.10 grams (31.69 drams) for 1927-1928 and in 1928-1929 Pen averaged 54.40 grams (30.74 drams). The combined average for Pen No.1 was 54.96 grams (31.05 drams) and for the mineral Pen No.2 was 55.39 grams (31.24 drams).

EXPERIMENT NO.VI. THE RELATION OF UNLIMITED
DRIED SKIM MILK TO EGG WEIGHT.

OBJECT.

To endeavour to increase egg size by feeding milk in addition to a standard laying ration.

PREVIOUS HISTORY.

Experiments with various protein foods at Idaho (PARKHURST 1927) indicated very definitely that unlimited sour skim milk was of value in the production of large eggs.

MATERIAL.

Two pens of Cuckoo Leghorn/Rhode Island Red cross pullets in the same house were started on the comparison on April 10th 1932, after a preliminary period of one month from March 10th 1932. Pen No.H1 received the standard ration and in addition a hopper of dried (Dutch Machine made) skim milk, to which the birds in the pen had free access. Each day dried skim/

skim milk was taken from the hopper and put into solution with warm water in such a way that the birds had an unlimited quantity of the liquid skim milk so produced. In addition, dried skim milk was scattered over the dry mash several times daily. Pen No. H2 had the standard ration only. It consisted of a scratch food of equal parts wheat, oats and kibbled maize, water oyster shell, grit and green food and a dry mash of 25 parts thirds, 20 parts wheat bran, 40 parts maize meal, 5 parts (60% protein) meat meal, 5 parts (60% protein) fish meal, and 5 parts extracted soya bean meal. Two per cent of cod liver oil was added to the grain food.

RESULTS.

From April 10th to May 10th, 26 pounds of dried skim milk was consumed in the pen receiving it, or .31 ounces per bird per day. The egg production and egg size in both pens was excellent throughout the three months of the experiment. The egg production remained at about the same level during the pre-experimental and experimental periods in both pens, but tended to go down slightly in the post-experimental period. Egg size was best in both pens before milk feeding started than later and was slightly lower during the feeding period than during the month following it. It is concluded that the feeding of extra quantities of dried/

dried skim milk under the conditions of experiment, in which a standard ration was fed, did not materially affect the egg size. There were indications in this experiment that during April or early in May there is a period during which egg size reaches a relatively lowest level and starts on an upward trend again.

EXPERIMENT NO.VII. THE RELATION OF AMOUNT
OF PROTEIN TO EGG WEIGHT.

OBJECT.

To compare two rations having similar chemical compositions except that they vary in their crude protein content.

PREVIOUS HISTORY.

There were some indications from the Idaho experiments (PARKHURST 1927) that the quantity of protein might be a factor in egg weight.

MATERIAL.

The experiment started September 27th 1929 and the first group consisted at the commencement of the experiment of 40 S.C. White Leghorn pullets in each pen. Forty eight weeks later, the second group was formed from 30 of the remaining birds which had become yearlings. The third group consisted of two pens of 30 pullets each, again over a forty eight week/



week period and during 1930-1931. All three groups were housed in similar pens in the same house and given identical feeding and management except for the rations under comparison. The all-mash method of feeding was used and no scratch food was given at any time. All pens received green food at the rate of two pounds per pen daily, when they did not have access to the runs, and grit, oyster shell, and water were always available to the birds. Artificial illumination was used in all groups.

The Standard Institute (1929) All-mash Ration was compared with a lower protein All-mash Ration in all three groups. The two rations were constituted as follows:-

	STANDARD(1929) MASH.	"LOW PROTEIN" MASH.
Yellow corn meal (maize)	49	59
Middlings	14	14
Bran	14	14
Meat and bone meal	6	2
Dried skim milk	6	2
Extracted soya bean meal	6	2
Cod liver oil	2	2
Ground limestone	2	2
Salt	1	1
Bone ash	-	2

CHEMICAL/

CHEMICAL ANALYSIS.

NUTRIMENT	STANDARD (1929) MASH	"LOW PROTEIN MASH"
Crude Protein	15.75	11.75
Ash	8.30	7.85
Oil	5.10	5.87
Crude Fibre	3.05	2.80
Carbohydrates	56.80	59.81
Moisture	11.00	11.92

RESULTS.

The first year (1929-1930), the average egg weight was 56.00 grams (31.67 drams) for the standard pen and 55.47 grams (31.34 drams) for the low protein pen, the difference being only slight. The standard pen completed the year with 39 birds and the low protein pen with 31 birds. In their second year 1930-1931, there was no significant difference in egg size between the pens, the average weights being 58.64 grams (33.07 drams) for the standard and 57.84 grams (32.57 drams) for the low protein rations. 26 birds completed the experimental year for the standard pen and 25 for the low protein pen.

During 1930-1931, two more pullet pens were compared on the same rations and there was no significant difference in egg size between them. The standard ration completing the year with 30 birds averaged 55.97 grams/

grams (31.32 drams) and the low protein ration averaging 55.93 grams (31.66 drams) completed the year with 27 birds.

It would seem from these results that the quantity of protein is not a factor in determining egg size unless possibly there is a deficiency. There are no indications that there was a protein deficiency in the low protein ration used. There was no significant difference in the egg production in the three groups as between the standard and the "low protein" pen.

EXPERIMENT NO.VIII. THE RELATION OF
MIXED PROTEIN RATIONS TO EGG SIZE.

OBJECT.

To find out if, in a mixed protein diet, an inter-change of protein foods will result in any influence being exerted on egg weight.

PREVIOUS HISTORY.

There were some indications from EXPERIMENT IV. that the use of fish meal would result in a larger egg weight than when earth nut meal, and possibly meat meal or extracted soya bean meal, were used.

MATERIAL.

This experiment consists of four pens of S.C. White Leghorns. The experiment started September 27th, 1929 with forty pullets per pen, and, after the first experimental period of 48 weeks, 30 of the remaining/

remaining yearlings were carried on with the same rations for another experimental year. The basal rations was the same as that used in the "Standard" pen in EXPERIMENT NO.VII. and the management and method of feeding was also similar. The comparisons were made of various mixed protein rations in which fish meal replaced meat and bone meal, dried buttermilk replaced dried skim milk, and decorticated earth nut meal replaced extracted soya bean meal in the basal ration.

The rations were as follows:-

INGREDIENTS.	PEN NO.1 BASAL.	PEN NO.2 FISH MEAL.	PEN NO.3 DRIED BUT- TER MILK	PEN NO.4 EARTH NUT MEAL.
Yellow corn meal	49	49	49	49
Bran	14	14	14	14
Middlings	14	14	14	14
Meat and bone meal	6	-	6	6
Dried skim milk	6	6	-	6
Extracted soya bean meal	6	6	6	-
Fish meal	-	6	-	-
Dried buttermilk	-	-	6	-
Dec. earth nut meal	-	-	-	6
Salt	1	1	1	1
Medicinal cod liver oil	2	2	2	2
Ground limestone	2	2	2	2

All parts being by weight.

FOOD ANALYSIS/

FOOD ANALYSES.

The analyses of mashes and the ingredients under comparison are given below:-

	BASAL MASH. PEN 3	FISH MEAL MASH. PEN 7.	BUTTERMILK MASH. PEN 8.	EARTHNUIT MASH PEN 9.
Oil	5.10	4.90	5.93	6.17
Moisture	11.00	11.00	10.85	10.55
Grude Protein	15.75	17.15	15.84	16.10
Grude fibre	3.05	3.00	3.32	2.95
Ash	8.30	7.12	8.00	7.77
Carbohydrates	56.80	56.83	56.04	56.46

The only material difference in the chemical analysis of the rations probably lies in the higher protein content of the fish meal mash used in Pen No. 7, as in every other chemical constituent they are of very similar composition.

ANALYSES OF PROTEIN RICH FOODS.

	MEAT AND BONE MEAL	SOYA BEAN MEAL	FISH MEAL	EARTHNOT	DRIED SKIM MILK	DRIED BUTTERMILK
Oil	14.87	1.07	4.50	9.25	0.25	5.35
Moisture	7.05	9.12	7.88	10.80	7.75	18.80
Crude Protein	39.99	44.01	65.60	46.55	33.25	26.25
Crude Fibre	7.10	5.30	-	5.52	-	-
Ash	35.00	7.30	22.02	4.42	7.50	9.10
Nitrogen free extract	2.90	33.20	-	23.46	51.25	40.50

57.

The fish meal used was of very good quality and the meat and bone meal of very ordinary grade. The dried skim milk used analysed higher in both protein and nitrogen free extract than the dried butter milk.

RESULTS:

As a result of a study of the variance in the four pens and the magnitude of the difference as compared to the standard errors of the differences, there were no significant differences found between any of the pens in either year. It can be seen from TABLE No. 10, that the differences are small. The pullet egg size was not good. The general tendency to larger egg size for fish meal over the meat and bone meal, and for earth nut meal to give smaller eggs than soya bean meal is in agreement with previous work. Egg size again dropped in the May-June period during both years. There was no indication that this drop in egg size was associated with lower food consumption.

TABLE NO.X.

TABLE No. X.

THE AVERAGE EGG WEIGHTS OF PENS ON VARIOUS MIXED PROTEIN RATIONS.

PEN No.	RATION	PULLET YEAR 1929-1930		No. birds at end of experiment	YEARLING YEAR 1930-1931		
		DRAMS	GRAMS		DRAMS	GRAMS	
1	(Meat and bone meal Basal (Dried skim milk (Soya bean meal	31.64	55.98	39	35.13	58.64	No. birds at end of experiment 26
2	Fish meal	31.83	56.34	34	33.57	59.42	24
3	Dried butter milk	32.26	57.07	37	33.62	59.49	29
4	Barth nut meal	31.41	55.59	37	32.61	57.42	26

59.

EXPERIMENT/

EXPERIMENT No.IX. A COMPARISON OF A MIXED PROTEIN
AND A SIMPLE PROTEIN RATION FOR EGG WEIGHT.

OBJECT:

To find out if any increase in egg weight results when two rations of practically the same crude protein content differ in the make-up of their protein ingredients.

MATERIAL:

There were two pens compared over a two year period and the feeding and general management was the same as in EXPERIMENT No.VII. The basal ration of this experiment was the same as the standard basal mash used in EXPERIMENTS No.VII. & VIII. This ration containing meat and bone meal, dried skim milk and extracted soya bean meal was compared with the same ration only with 12 parts meat and bone meal replacing the 6 parts each of the other two foods, soya bean meal and dried skim milk. The analyses of the two rations were as follows:

	ANALYSIS OF BASAL MASH.	SIMPLE PROTEIN MASH.
Oil	5.10	7.12
Moisture	11.00	10.45
Crude protein	15.75	16.53
Crude fibre	3.05	3.02
Ash	8.30	12.30
Carbohydrates	56.80	50.58

The/

The ash content was somewhat higher in the "Simple Protein" mash.

RESULTS:

During the pullet year, 38 birds completed the year in the Simple Protein pen and 39 birds in the Basal mash pen. During the pullet year the simple protein pen averaged 56.92 grams (32.16 drams) and the mixed protein pen averaged 55.98 grams (31.64 drams). The averages for the yearling was 58.94 grams (33.30 drams) for the simple protein pen which contained 27 birds at the completion of the experiment and 58.64 grams (33.13 drams) for the mixed protein pen which finished with 26 birds. An analysis of the variance between the pens showed that there was not any significant difference between the two pens.

SUMMARY/

S U M M A R Y

S.C. White Leghorn and White Wyandotte pullets housed behind ordinary glass and not given adequate amounts of vitamin D gave significantly lower average egg weights than comparable pens given adequate quantities of the anti-rachitic vitamin. The egg size was not significantly less in the irradiated ergosterol pen than it was in the cod liver oil pen.

There was no significant difference in the egg weights for lighted and unlighted pens of Single Comb White Leghorn pullets.

An all-in-one ration in pellet form gave significantly larger egg size than the same ration in mash form for both pullets and yearlings of the White Leghorn breed.

Under the conditions of the experiment, both green food and oyster shell proved of value in increasing egg size when supplementing "All in one" rations.

Fish meal proved definitely of greater value for egg size than decorticated extracted earth nut meal (peanut meal) and was slightly more valuable than extracted soya bean meal or meat meal.

A mineral supplement did not materially increase the egg size when used with a meat meal ration, unlimited oyster shell being available.

When/

When a standard ration was fed to Cuckoo Leghorn/Rhode Island Red cross pullets, egg size was not materially affected by the feeding of extra quantities of dried skim milk.

When two rations of similar constitution and mineral analysis, but varying in protein content, were compared, there was no significant difference in egg size.

There were no significant differences in egg size for either pullets or yearling Leghorns when fish meal replaced meat and bone meal, dried butter milk replaced dried skim milk, or decorticated earth nut meal (peanut meal) replaced extracted soya bean meal in a mixed protein ration.

A mixed protein ration did not give a larger egg size than a simple protein ration.

There were indications in several of the experiments that about April or May there is a turning point in an egg weight cycle.

Further research is required to determine the relation of the protein and mineral content of the ration to the size of the eggs produced. It has not been possible to confirm previous work that proteins or minerals are of special value in regard to egg weight.

D

THE EFFECT OF THE ORAL ADMINISTRATION OF DRIED
ANTERIOR LOBE OF PITUITARY ON PRODUCTION AND
EGG WEIGHT IN THE DOMESTIC FOWL.

INTRODUCTION

CLARK (1915) reported a remarkable increase in egg production followed the feeding of Anterior Lobe of Pituitary to chickens. PEARL (1916) pointed out that Clark's figures showed no fluctuation greater than normally to be expected and reported negative results from feeding pituitary substance. SIMPSON (1923) found no evidence of the marked increase in egg production reported by Clark when similar material and procedure was used.

GUTOWSKA (1930), (1931), reported positive results from the per-oral administration of pituitary anterior lobe to laying hens as evidenced by increases in egg size, egg number, and in the weight of the birds as well as certain ovarian changes.

It was through the co-operation of Dr. Marie Gutowska that these experiments were undertaken. The hormone substance used was, through her assistance, obtained gratis from the Ludwik Spiess i Syn, Warsaw, Poland/

Poland. It was prepared from the entire "glandular pituitaria pars anterior" using the acetone drying method, no milk sugar being added. The pituitary substance used in the first two experiments was found on testing with immature female mice to be more potent in the gonadotropic hormones than the material used in the third experiment. Both preparations, however, were shown to be positive in inducing follicle growth, formation of corpus luteum, and oestrus in more than 60 per cent of the animals tested. Neither preparation contained appreciable amounts of the ovarian hormone as tested on oöphorectomized mice. The rhythm of time of laying and the cycle of egg production and egg size were used to study the physiological reaction of the fowls. The total weight of eggs previous to and during treatment was also recorded and summarized. In the first experiment, the production was good, in the second experiment it was poor, and in the third experiment it was very good.

Method/



Method used to give capsules of the dried anterior pituitary substance to the fowls treated. After placing capsule in the mouth, it was gently worked down to the crop.

EXPERIMENT I.

TABLE I. Results of Per-oral Administration of Anterior Lobe Pituitary.

PEN NO. 9.

Pre-experimental period (May 11th-28th, 1931. 18 days)

TREATED PULLET NOS.	NO. of EGGS	TOTAL WGT. in GRAMS	AVGE. WGT. in GRAMS	UNTREATED PULLET NOS.	NO. of EGGS	TOTAL WGT. in GRMS	AVGE. WGT. in GRMS.
1645	14	733	52.36	1649	9	485	53.89
1665	9	509	56.56	1643	16	900	56.25
1655	11	648	58.91	1646	14	823	58.79
TOTAL	34	1890	55.53	TOTAL	39	2208	56.87

Experimental Period (May 29th-June 15th, 1931. 18 days)

1645	9	509	56.53	1649	7	399	57.07
1665	12	717	59.76	1643	17	992	58.33
1655	12	741	61.77	1646	16	954	59.65
TOTAL	33	1967	59.61	TOTAL	40	2345	58.64
Difference	-1	+77	+4.08		+1	+37	+1.77

EXPERIMENT I.

Rhode Island Red pullets were used in the experiment which started May 11th, 1931. After the eggs had been weighed for eighteen days, sixteen individuals were selected from two pens (9 and 10) which were being fed slightly different rations. Basing the selection on the records made during the 18-day pre-experimental period, each pituitary-fed fowl was paired with a comparable control. One pullet went broody and failed to lay after the pre-experimental period and her record, and that of her control, were deleted. Doses of .75 grams of the dessicated anterior lobe pituitary were administered in gelatin capsules per oral daily at 7 to 8 p.m. for 10 days to June 6th. Double doses were given the birds from pen 10, for three additional days, to June 9th, making 13 days in all.

TABLE I.

If the records of the treated birds in pen 9 are compared with their controls it can be easily observed that although there was a slight tendency for the treated birds to lay larger eggs, the differences are not significant when comparison is made with the controls. Every bird whether treated or not gave a larger/

EXPERIMENT I. (contd.)

TABLE I. Results of Per-oral Administration of
Anterior Lobe Pituitary.

PEN NO. 10.

Pre-experimental Period (May 11th-28th, 1931) 18 days).

TREATED PULLET NOS.	NO. of EGGS	TOTAL WGT. in GRMS.	AVGE. WGT. in GRMS.	UNTREAT- ED PULLET NOS.	NO. of EGGS	TOTAL WGT. in GRMS.	AVGE. WGT. in GRMS.
1628	14	790	56.43	1620	15	784	52.27
1637	14	766	54.71	1622	13	709	54.54
1630	12	715	59.58	1614	14	851	60.79
1632	3	175	58.33	1621	8	469	58.62
TOTAL	43	2446	56.88	TOTAL	50	2813	56.26

Experimental Period (May 29th-June 15th, 1931. 18 days).

1628	14	808	57.73	1620	14	770	55.04
1637	12	677	56.40	1622	11	654	59.47
1630	15	927	61.81	1614	13	779	59.95
1632	13	837	64.40	1621	9	554	61.55
TOTAL	54	3249	60.17	TOTAL	47	2758	58.68
Difference	+11	+803	+3.29		-3	-55	+2.42

larger average egg weight during the experimental period. There was no material difference in egg production. In pen 10, with one exception, all the birds again laid larger eggs during the experimental period. The greater production in the treated group was due almost entirely to one bird; 1632. From these and the charts of the cycles of time of laying and daily egg weights, one would conclude that the per oral administration of anterior lobe pituitary had not affected the birds in any way.

EXPERIMENT II

Cuckoo Leghorn x Rhode Island Red first cross pullets were used in this comparison and three pairs were selected as uniformly as possible on the basis of their previous records as to egg production and egg weight as well as their body weights on January 6th, 1932. The eggs were weighed to the nearest dram from December 21st. to February 21st. Capsules of the same dessicated anterior pituitary lobe as used in EXPERIMENT I were, from January 3rd to February 7th inclusive, placed in the crop of the bird daily at 6 to 7 p.m. The daily dose was from .8 to 1 gram. The "treated" pullets were weighed on January 6th and again on February 11th. The average weight on January 6th was/

EXPERIMENT II.

TABLE II. Results of Per-oral Administration of Anterior Lobe Pituitary.

Pre-experimental Period (Dec. 21st 1931-Jan. 2nd, 1932. 13 days).							
TREATED PULLET NOS.	NO. of EGGS	TOTAL WGT. in GRMS.	AVGE. WGT. in GRMS.	UNTREATED PULLET NOS.	NO. of EGGS	TOTAL WGT. in GRMS.	AVGE. WGT. in GRMS.
1017	4	210	52.50	1008	2	114	57.00
1052	3	148	49.25	1092	2	99	49.50
1047	2	118	59.00	1055	2	106	53.00
1033	2	107	53.50	1049	3	162	54.00
1075	4	238	59.50	1094	0	0	0
1100	3	144	48.00	1073	3	166	55.33
TOTALS	18	965	53.61		12	647	53.91
Experimental Period (Jan. 3rd.-Feb. 7th, 1932. 36 days).							
1017	5	247	49.50	1008	8	387	48.37
1052	6	292	48.66	1092	5	253	50.60
1047	8	453	56.62	1055	17	965	56.76
1033	13	711	54.70	1049	5	266	53.20
1075	7	423	60.43	1094	7	413	59.00
1100	6	276	46.00	1073	9	465	51.66
TOTALS	45	2402	53.37		51	2749	53.90

was 2198.83 grams and on February 11th was 1914.50, a loss of 284.33 grams.

TABLE II.

It can be seen from TABLE II that the production during the pre-experimental period was not good in either the treated birds or their controls. This was probably due to a deficiency of Vitamin D in the ration which was made good early in February with the result that all birds laid better during the experimental and post-experimental periods. A comparison of the number of eggs and their average weight shows clearly that there was no physiological reaction apparent from the administration, over the prolonged period of 36 days, of the pituitary substance. During the post-experimental period, there were two treated birds that did not lay. It makes little difference in the results as to whether or not the records of their controls are included, as in either case the numbers of eggs and their average weight were greater in the control group. It is only possible to conclude from this experiment that there was no effect on egg production or egg size from the per oral administration of anterior lobe pituitary substance.

EXPERIMENT II. (contd.)

TABLE II. Results of Per-oral Administration of Anterior Lobe Pituitary.

Post-experimental Period (Feb.8th-Feb.20th,1932.13 days)

TREATED PULLET NOS.	NO. of EGGS	TOTAL WGT. in GRMS.	AVGE. WGT. in GRMS.	UNTREATED PULLET NOS.	NO. of EGGS	TOTAL WGT. in GRMS.	AVGE. WGT. in GRMS.
1017	8	434	54.25	1008	10	595	59.50
1052	0	-	-	1092	8	432	54.00
1047	6	339	56.50	1055	10	612	61.20
1033	9	537	59.65	1049	5	315	63.00
1075	0	-	-	1094	7	420	60.00
1100	8	401	50.12	1073	8	445	55.62
TOTALS	31	1717	55.19		48	2819	58.73

EXPERIMENT III.

TABLE III.

TREATED PULLETS NO.	BODY WEIGHT in GRMS.	CONTROL PULLETS NO.	BODY WEIGHT in GRMS.
1008	2240	1027	2212
1009	2096	1015	2152
1014	2214	1028	2126
1026	1986	1039	2327
1011	2356	1018	2383
1005	2353	1021	2270
1002	2276	1040	2240
1012	2417	1016	2411
1036	2298	1037	2212
1029	2124	1022	2355
1031	2246	1043	2327

EXPERIMENT III.

Because the production was relatively poor in EXPERIMENT II, another experiment was started on February 8th. 1932, again using Cuckoo Leghorn x Rhode Island Red first cross pullets and new Anterior Pituitary Lobe substance which was received from Ludwik. Speiss i Syn, of Poland. Pairs of birds were again selected on the basis of the records of egg size and production up to date and the administration of the doses began on February 22nd. The birds had previously been weighed on February 11th. The paired birds and their weights are given in TABLE III.

TABLE III.

The normal dose was, as in EXPERIMENT II, .8 to 1 gram per bird daily and the gelatine capsule was moistened, placed in the bird's mouth and worked down into her crop. The doses were given daily for three days (February 22nd to 24th inclusive), not given for three days (February 25th to 27th), given for seven days (February 28th to March 5th), and seven days (March 6th to 13th) missed. For the next five days (March 14th to 18th), pullets No. 1008, 1009, 1011, and 1012 were given double doses at 7 a.m. instead of/

of the normal doses in the evening at 6 to 7 p.m. No capsules were given for the 14 days from March 19th to April 1st, at which time the experiment ended.

TABLE IV.

TABLE IV. gives the numbers and weights of the eggs laid by each treated bird and its control together with the totals and averages for each group. The production throughout this experiment was, in contrast to EXPERIMENT II, excellent and increased during the course of the experiment about equally in the two groups. The two groups had only .36 of a gram difference in their egg size for the pre-experimental period of 14 days and the averages for the two groups do not at any time during the experimental periods or during the post-experiment period differ by more than .67 of a gram. Considering the averages within the groups, it can be seen that there is at no time a difference in the averages for the treated group that would lead to the conclusion that the treatment had affected either production or egg size significantly.

TABLE IV. Results of Per-oral Administration of Anterior Lobe Pituitary

Pre-experimental Period 14 days (Feb. 8th. - 21st.)			Treated 3 days			Untreated 3 days		
TREATED PULLET NOS.	NO. of EGGS	TOTAL WEIGHT in GRMS.	AVERAGE WEIGHT in GRMS.	NO. of EGGS	TOTAL WEIGHT in GRMS.	AVERAGE WEIGHT in GRMS.	NO. of EGGS	TOTAL WEIGHT in GRMS.
1008	10	595	59.50	3	180	60.00	2	122
1009	11	598	54.36	1	55	55.00	2	111
1011	10	610	61.00	2	121	60.50	3	179
1012	11	625	56.81	2	112	56.00	2	110
1014	8	522	65.25	2	136	68.00	3	192
1026	9	517	57.44	2	115	57.50	2	113
1005	7	450	64.28	2	128	64.00	1	62
1002	7	401	57.28	3	182	60.66	2	125
1036	8	473	59.12	1	59	59.00	1	56
1029	6	369	61.50	2	127	63.50	3	180
1031	9	575	63.76	2	129	64.50	2	125
TOTALS	96	5735	59.74	22	1344	61.09	23	1375
1027	10	580	58.00	3	182	60.66	2	119
1015	2	109	54.50	1	53	53.00	3	172
1018	9	525	58.32	2	112	56.00	2	112
1016	9	544	60.44	3	185	61.66	2	122
1028	10	626	62.60	3	184	61.33	2	125
1039	11	670	60.91	2	123	61.50	2	122
1021	5	319	63.80	2	124	62.00	3	195
1040	10	568	56.80	2	109	54.50	3	164
1037	8	476	59.50	2	124	62.00	1	60
1022	10	607	60.70	2	119	59.50	3	183
1043	7	445	63.57	3	197	65.66	1	66
TOTALS	91	5469	60.10	25	1512	60.48	24	1440

Treated
7 daysUntreated
7 daysDouble dosed
5 days(Post Experimental Period)
March 9th April 1st.
Untreated 14 days

AVERAGE WEIGHT in GRMS.	NO. of EGGS	TOTAL WEIGHT in GRMS.	AVERAGE WEIGHT in GRMS.	NO. of EGGS	TOTAL WEIGHT in GRMS.	AVERAGE WEIGHT in GRMS.	NO. of EGGS	TOTAL WEIGHT in GRMS.	AVERAGE WEIGHT in GRMS.	NO. of EGGS	TOTAL WEIGHT in GRMS.	AVERAGE WEIGHT in GRMS.	NO. of EGGS	TOTAL WEIGHT in GRMS.	AVERAGE WEIGHT in GRMS.
61.00	5	300	60.00	7	415	59.28	4	243	60.75	x	-	-	-	-	-
55.50	5	278	55.60	7	398	56.85	x 4	227	56.75	x	-	-	-	-	-
59.66	5	301	60.20	7	417	59.57	x 5	304	60.80	x	-	-	-	-	-
55.00	6	333	55.50	6	332	55.33	x 4	215	53.75	-	-	-	-	-	-
64.00	5	331	66.20	6	399	66.50	-	-	-	-	-	-	-	-	-
56.50	5	275	55.00	5	281	56.20	-	-	-	-	-	-	-	-	-
62.00	5	314	62.80	4	247	61.75	-	-	-	-	-	-	-	-	-
62.50	4	249	62.25	4	242	60.50	-	-	-	-	-	-	-	-	-
56.00	6	349	58.16	5	293	58.60	-	-	-	-	-	-	-	-	-
60.00	5	306	61.20	6	364	60.66	-	-	-	-	-	-	-	-	-
62.50	4	252	63.00	5	321	64.20	-	-	-	-	-	-	-	-	-
59.78	55	3288	59.78	62	3709	59.82	x 17	989	58.17	-	-	-	-	-	-
Untreated.			x 4 Birds double dosed for 5 days.												
59.50	5	288	57.60	7	395	56.43	x 4	230	57.50	-	-	-	-	-	-
57.33	5	296	59.20	5	302	60.40	x 4	235	58.75	-	-	-	-	-	-
56.00	6	339	56.50	5	300	60.00	x 4	228	57.00	-	-	-	-	-	-
61.00	5	302	60.40	7	433	61.87	x 4	241	60.25	-	-	-	-	-	-
62.50	3	186	62.00	7	422	60.28	-	-	-	-	-	-	-	-	-
61.00	6	355	59.16	8	469	58.62	-	-	-	-	-	-	-	-	-
65.00	4	260	65.00	6	379	63.16	-	-	-	-	-	-	-	-	-
54.66	5	280	56.00	5	281	56.20	-	-	-	-	-	-	-	-	-
60.00	4	242	60.50	5	300	60.00	-	-	-	-	-	-	-	-	-
61.00	6	356	59.33	6	361	60.16	-	-	-	-	-	-	-	-	-
66.00	5	324	64.80	6	386	64.33	-	-	-	-	-	-	-	-	-
60.00	54	3228	59.77	67	4028	60.12	x 16	934	58.37	-	-	-	-	-	-
Controls for			4 Birds double dosed 5 days.												

NO. of EGGS x	TOTAL WEIGHT in GRMS.	AVERAGE WEIGHT in GRMS.
11	646	58.72
x 12	661	55.08
x 12	707	59.00
x 12	652	54.33
12	803	66.91
11	615	55.91
10	612	61.20
8	446	55.75
14	776	55.43
10	589	58.90
9	570	63.33
x 47	2666	56.70
121	7077	58.49
x 12	693	57.91
x 12	693	58.00
x 10	562	56.20
x 10	605	60.50
14	840	60.00
13	737	56.69
11	691	62.1
9	506	56.22
9	541	60.11
11	656	59.63
11	689	62.63
44	2558	58.14
122	7218	59.16

Total all treated
pulletsTotal all control
pullets

S U M M A R Y.

1. The experiments were concerned with the feeding of dried anterior lobe pituitary in various amounts and for various lengths of times to laying pullets.
2. It was not possible to observe any marked influence on the number, weight, rhythm, or egg weight cycle of treated pullets as compared to their carefully selected controls under the conditions of these experiments.

E
THE EFFECT of INJECTIONS of an ANTERIOR PITUITARY
SEX HORMONE SUBSTANCE on the EGG RHYTHM and EGG
WEIGHT CYCLES in LAYING HENS.

I N T R O D U C T I O N .

WALKER (1925) reported that fresh anterior hypophyseal substance injected intraperitoneally inhibited ovulation in the fowl. FRIEDMAN (1929) found that the intravenous injection of urine of pregnant women provokes ovulation in the rabbit while the intraperitoneal injection of similar urine produces luteinization of follicles without ovulation. PIGHINI (1929) reported that doses of follicular fluid in physiological amounts stimulated ovulation in turkeys and chickens. LOSSER (1930) reported that powdered anterior lobe inhibited ovulation in mature hens. JUHN and GUSTAFSON (1930) reported as a result of injecting human placental hormone in fowls that the hormones of either sex are not species specific so far as birds and mammals are concerned and that the hormone retains its full activity in the organism for a relatively short period only after injection, the time being about 24 hours.

ASMUNDSON (1931) reviewed the literature in the effect of hormones on the formation of the hen's egg and reported that there was no apparent effect on the weights of the eggs laid or the number laid when up to 2.25 cc. (containing about 30 rat units per cc).
of/

of an aqueous solution of follicular hormone (Estrogen) was injected into a Leghorn pullet. NOETHER (1931) found the hen peculiarly adapted for tests of inhibiting properties of anterior lobe of the hypophysis. Intraperitoneal injection of fresh extract produced on the laying hen an interruption in ovulation of 21 days. Extracts of fresh urine from pregnant women were without effect, indicating either that the active substance in the urine is different from that in the hypophysis anterior lobe, or that the hypophyseal substance is too sparingly present in the urine to affect the hen.

PROCEDURE.

In this experiment, a preparation containing the anterior pituitary sex hormones, especially the follicular and luteinizing factors, was injected daily into laying hens. The hormone powder used was Follutein Squibb and was stated to have a potency of 5000 units per gram, and to be free from the growth hormones.

The hormone powder was put into solution in sterile normal saline and 2 cc. of the warm solution daily were injected. Crossbred Cuckoo Leghorn x Rhode Island Red pullets were used in these studies and the physiological re-action measured by the effect on the rhythm/

rhythm of the time of egg laying and of the weights of the eggs laid. Normally, the first egg in a cycle is laid early in the morning and is larger than the subsequent eggs in the cycle, which are usually laid later in the day. The cycle is not sufficiently fixed as an individual character of a fowl that some variations will not occur. One of the objects of these experiments was to show that it is a more reliable measure of the physiological activity of the fowl than that of numbers and weight of eggs only.

EXPERIMENT I.

All the pullets used were from a pen of birds that had been laying well during the Autumn. Pullet 1083 laid one egg weighing 62 grams at 4 o'clock on December 23rd, 1931, and eggs weighing 59 and 64 grams respectively at 2 p.m. and 4 p.m. January 1st. and 2nd. 1932. She was injected intravenously (occasionally subcutaneously) from January 3rd. to 9th. (inclusive) with 2 cc of solution of 20 milligrams of Follutein (approximately 100 units). She did not lay from January 3rd. to January 19th. On the 19th she laid a 55 gram egg at 2 p.m. and she was injected intravenously on January 20th at 4 p.m. At the same time, a control Pullet No. 1084, was injected with 2 cc. of saline solution only, also intravenously. She had also laid the previous day. Both pullets were injected subcutaneously on the 21st. at 7 p.m., 1083 having laid a 60 gram egg at 2 p.m. that day. An intravenous injection was made at 5 p.m. into 1083 on January 24th after she had just laid a 61 gram egg. Pullet 1083 laid a 62 gram egg at 7 a.m. on Jan 26th and then stopped until Feb. 5th. a period of 9 days. Pullet 1084 laid one more egg, weighing 52 grms and stopped laying to Feb. 5th, a period of 13 days. The fact that both the injected/

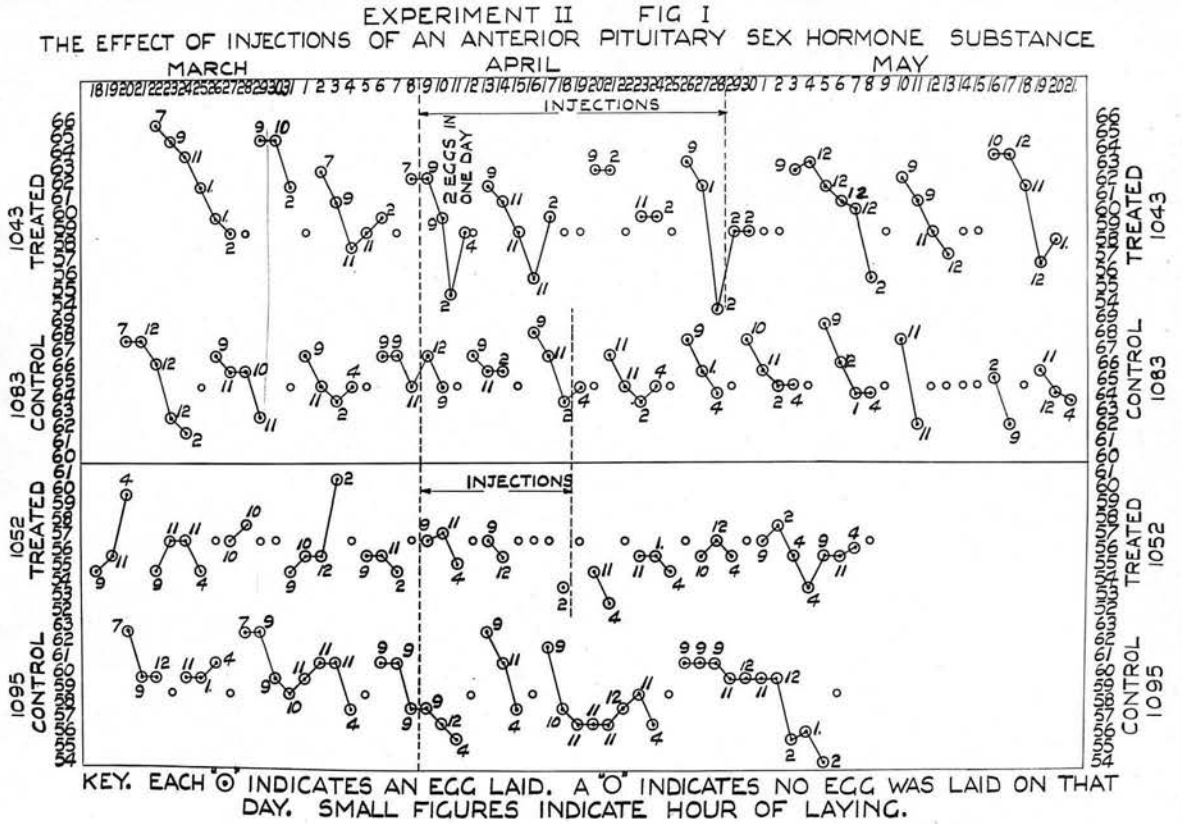
injected bird and its control stopped laying would indicate that some other factor was responsible for it other than the injection of follutein. It is probable that there was a deficiency of vitamin D in the ration at the time and this affected the production.

EXPERIMENT II.

Four pullets, 1083, 1043, 1052 and 1095 were included in the experiment which started about March 18th, 1932. After the pre-experimental period No.1043 was injected with 2 cc. of Follutein solution daily from April 9th to April 28th, inclusive. Twenty milligrams of the hormone powder (as in Experiment I) was used from April 9th to 18th, 30 milligrams from the 19th to the 24th and 20 milligrams from the 25th to the 28th. About two thirds of the injections were intravenous but in a third of the cases about one half of the solution entered the bird subcutaneously. No.1083 was injected with saline solution only intravenously (partly subcutaneously) from April 9th to 28th, and continued to lay well. No.1052 was injected from April 9th to 18th with 20 milligrams of powder in 2 cc saline (approximately 100 units). No.1095 was injected with warm saline solution only intravenously daily from April 9th through to April 18th, and continued to lay well throughout/

EXPERIMENT II. FIG. I

THE EFFECT OF INJECTIONS OF AN ANTERIOR PITUITARY SEX HORMONE SUBSTANCE.



throughout the injections.

FIG. NO. I. shows the rhythm of the time of egg laying and of egg size of the four pullets. A study of this graph of the time of laying and the egg weights of No. 1043 does not reveal any indications that the injections of the follutein did increase the egg production or the size of the subsequent eggs laid. It is of interest that ovulation was not inhibited as reported by WALKER (1925) when fresh pituitary substance was injected intraperitoneally. She laid two eggs on April 11th and both before and during the injections showed an irregular rhythm. Her eggs tended to be smaller in size during and after the injections than just previous to them. There was no apparent effect (FIG. 1) on No. 1052, due to her being injected. No. 1095 showed a more regular and continuous rhythm during and after the injections with saline solution than before (see FIG. I) Her sequencies were long and regular. The cold injections of saline given to No. 1083 apparently did not adversely affect her. She continued to lay at about the same rate as previously and her egg size was also about the same. Pullet No. 1043 (see FIG. I) started on a normal cycle on March 22nd at 7 a.m., laid later each day and after laying at 2 p.m. on the 27th, stopped laying for a day and started again at 9 a.m. on the 29th. Her rhythm became irregular on the 4th of April before/

before the injections had started and are not sufficiently abnormal to justify stating that the Follutein has effected her physiologically.

TABLES I and II give details of the numbers of clutches, size of clutch and average egg weight for each clutch throughout the experiment. The egg production was good for all the birds and clutch size was large enough to show variations either in time of laying or egg size. It is not possible to detect any abnormal variation which might have been due to the injections of Follutein.

S U M M A R Y .

1. Under the conditions of the experiments, the number and size of egg was not influenced materially by the injection of an anterior lobe pituitary sex hormone substance, Follutein.
2. It is claimed that the number and size of clutch, the mean weight of egg in the clutch, and the rhythm of time of laying and egg weights are a better criterion of the physiological activity of the fowl than number of eggs and or mean weight of eggs only.

EXPERIMENT II.

TABLE I. Comparison of Clutches of eggs before, during, and after injections for Pullet No.1043 and the Control Pullet No.1083.

Pre-experimental Period (March 20th to April 8th.)

PULLET No.1043.				PULLET No.1083 Control			
CLUTCH NO.	NO. of EGGS	TOTAL WEIGHT in grms.	AVERAGE WEIGHT in grms.	CLUTCH NO.	NO. of EGGS	TOTAL WEIGHT in grms.	AVERAGE WEIGHT in grms.
1	6	376	62.66	1	5	327	65.80
2	3	192	64.00	2	4	262	65.50
3	5	301	60.20	3	4	261	65.25
				4	5	331	66.20
TOTAL	3	14	869	4	18	1181	65.61
		(Ave. 4.66)	62.07		(Ave. 4.50)		

Experimental Period (April 9th. to 28th. incl.^X)

1	5	298	59.60	1	3	199	66.33
2	5	298	59.60	2	4	266	66.50
3	2	126	63.00	3	2	132	66.00
4	2	120	60.00	4	2	134	67.00
5	5	297	59.40				
TOTAL	4	19	1139	4	11	731	66.45
AVERAGE		(Ave.4.75)	59.94		(Ave.2.75)		

X Clutches sometimes overlapped one way or the other by a day or two.

TABLE I. Comparisons of Clutches of eggs before, during and after injections for Pullet No.1043 and the Control Pullet No.1083.
Post-experimental Period (April 29th. to May 20th.)^x

PULLET No.1043.				PULLET No.1083. Control			
CLUTCH NO.	NO. of EGGS	TOTAL WEIGHT in grms.	AVERAGE WEIGHT in grms.	CLUTCH NO.	NO. of EGGS	TOTAL WEIGHT in grms.	AVERAGE WEIGHT in grms.
1	6	365	60.83	1	4	264	66.00
2	4	241	60.25	2	4	264	66.12
3	5	305	61.00	3	2	131	65.50
				4	2	128	64.00
				5	3	195	65.00
TOTAL 3	15 (Ave.5.00)	911	60.73	5	15 (Ave.3.00)	982	65.46

TABLE II. Comparison of Clutches of eggs before, during and after injections for Pullet No.1052 and the Control Pullet No.1095.
Pre-experimental Period Period (March 18th to April 7th)

PULLET 1052.				PULLET 1095 Control			
CLUTCH NO.	NO. of EGGS	TOTAL WEIGHT in grms.	AVERAGE WEIGHT in grms.	CLUTCH NO.	NO. of EGGS	TOTAL WEIGHT in grms.	AVERAGE WEIGHT in grms.
1	3	171	57.00	1	3	183	61.00
2	4	224	56.00	2	3	181	60.33
				3	3	186	62.00
3	2	115	57.50	4	8		60.00
4	4	228	57.00				
5	3	167	55.66				
TOTAL 5	16 (Ave.3.20)	905	56.56	4	12 (Ave.3)	730	60.83

^x Clutches sometimes overlapped one way or the other by a day or two.

EXPERIMENT II. (contd.)

TABLE II. Comparison of Clutches of eggs before, during and after injections for Pullet No.1052, and the Control Pullet No.1095.

Experimental Period (April 9th to 18th inclusive)^X

CLUTCH NO.	NO.of EGGS	TOTAL WEIGHT in grms.	AVERAGE WEIGHT in grms.	CLUTCH NO.	NO.of EGGS	TOTAL WEIGHT in grms.	AVERAGE WEIGHT in grms.	
1	3	170	56.66	1	6	351	58.50	
2	2	113	56.50					
3	1	54	54.00	2	3	182	60.66	
TOTAL	3	6	337	56.16	2	19	533	59.11

Post-experimental Period (April 18th. to May 7th.)^X

1	2	108	54.00	1	8	465	58.12
2	3	167	55.66	2	10	590	59.00
3	3	169	56.33				
4	7	394	56.28				
4	15 (Ave.3.75)	838	55.86	2	18 (Ave.9.00)	1055	58.61

^X Clutches sometimes overlapped one way or the other by a day or two.

DISCUSSION.

PART I.

DISCUSSION

The problem of egg weight in the domestic fowl is a difficult one because of the many factors which are known to influence the production of the egg. Although there seems to be adequate proof that egg size is inherited, there is a remarkable disagreement among investigators as to the method of inheritance. It is quite apparent that its inheritance cannot, at present, be explained on simple mendelian lines and it is highly probable that it will be found to involve multiple or complementary factors. Egg weight factors are apparently independent on a whole of production factors but it seems reasonable to suppose that linkage may be found between early maturity factors and small eggs as it has already been shown to exist between large clutch size and small eggs. In both cases, the nutritional and management factors which play such an important part in body maturity and the maintenance of body weight at maturity have to be carefully considered. Factors that appear to be genetic may not be genetic at all and only the result of inadequate knowledge of nutrition and management. Poor management and poor nutrition are important factors in egg size. There seems to be no doubt that a deficiency of proteins, either/

either in kind or quantity, unbalanced proteins and minerals, insufficient minerals, and inadequate quantities of Vitamin D are all factors which may cause egg size to be smaller. Giving insufficient food or forcing production without adequate maintenance for body weight is poor management, and may cause egg size to suffer. Body weight is one, if not the most important, of the factors correlated with egg weight within a breed. This may be due to nutrition and management or there may be linkage between body weight and egg weight factors. It is highly probable that both inheritance and physiological factors are involved.

The clutch and cycle of egg weight has not yet been satisfactorily explained. The fact that the fowl normally lays its largest egg in the morning and then takes a longer time to lay a smaller egg each succeeding day she lays is difficult to explain. It would indicate that some endocrine organ controlled the egg producing activity of the fowl. Because of its relation to the genital organs, the anterior lobe of pituitary would seem to be the logical source of this stimulus. It is probable that insufficient experimentation has yet been conducted to determine to what the egg weight rhythm is due and how it can be either modified or controlled.

The genetics and physiology of egg weight in fowls, in spite of the study already given to it, offers a rich field for further investigation.

PART II.

SEX LINKAGE IN THE DOMESTIC FOWL.

A REPORT OF EXPERIMENTS IN SUPPORT OF
THE MAIN THESIS.

SEX LINKAGE IN THE DOMESTIC FOWL.

INTRODUCTION

The inheritance of characters of the sex-linked group is of interest in relation to the genetics of poultry and a more accurate knowledge of them is of both scientific and practical importance. The sex-linked factors in poultry were among the first to be recognised as examples of sex-linked inheritance and barring and gold are two of the best known characters of this group. As the pullet is economically far more important than the cockerel and it may also be of value to handle the males differently from the females, the determination of sex at hatching is of considerable convenience in specialized poultry farming.

One of the earliest theories of the inheritance of egg production involved sex-linkage of high winter production. If, as some investigators believe, there are factors for egg production or egg weight carried on the sex chromosome, the linkage relations between these quantitative factors and easily recognized sex-linked external characters become of special interest and importance.

The/

The light breed cockerel has been one of the greatest problems which the commercial poultryman has to contend with, if he is specializing in egg production. For every pullet, he must incubate at least 4 to 5 eggs and, in most cases, it is the most economic method to destroy the males as soon as they can be recognized. A saving of food, time, and brooder space may result if only pullets are reared.

The sex-linked crosses most commonly employed in poultry production usually involve two breeds, one of which is nearly always a heavy breed with the result that the sex-linked cross has been generally of the broody type. It was primarily the object of this study, therefore, to discover factors that would be useful in determining the sex at hatching and also what breeds or varieties, having these factors, could be used commercially.

REVIEW OF LITERATURE.

SEX DETERMINATION.

In most domestic animals, there are external characteristics which make the sexes easily distinguishable at birth. The domestic fowl is one of the exceptions as there are no dependable signs of sex until it is at least a few weeks old.

There have been a great many theories proposed for the determination of sex in the egg and in the chicks at hatching. DUNN (1923) quotes the following extract from 'The Farmer's Magazine', London for January 1869, p. 25, "When, on examining the egg, by holding it between the eye and the sun, or of a candle, the vivifying speck is seen exactly on top, such an egg it is said, will produce a male bird; but if, on the contrary, the speck be on one side, it will produce a hen. It is said also, that the sex of the embryo bird may be distinguishable by the shape of the egg; as, if the egg is elongated in shape it will contain a male, but if more globular it will contain a female. So that, if these indications be true, either sex may be propagated at pleasure, which is not yet known to be the case in any/

any other class of the animal creation". Although there are many people who still believe in the latter theory, there is now sufficient evidence to show that these theories are not correct.

Size of egg has not been shown to be of any value in determining the actual sex of the chicken which may be hatched from it.

JULL & DUNN (1925) reported that there was (1) no significant difference between the weights of yearling hen ~~and~~ eggs from which males are hatched and the weight of yearling hen eggs from which pullets are hatched, (2) no significant difference in the weight of male chicks and the weight of female chicks from either pullet eggs or yearling hen eggs, and concluded that the separation of the sexes of chicks at hatching time on the basis of weight is unreliable.

DUNN (1923) also reports the results of the investigations of the Bureau of Chemistry of the U.S.W. Department of Agriculture into the use of so-called 'sex detectors', in which they were found to be useless and subsequently excluded from the U.S. mails. It is doubtful if many intelligent poultry breeders ever considered these devices sufficiently reliable to depend upon them but there was enough interest shown in them that undoubtedly thousands of them were sold.

DUNN (1923) reports data obtained at Storrs Agricultural Experiment Station on the individual weights/

weights of 11 31 day-old White Leghorn chicks which show that the male chicks had an average weight of 35.57 grams (1.254 ounces) while the average weight of the females was 35.44 grams (1.250 ounces). There was no possibility of distinguishing the sexes on the basis of size, as the variation in the males was from 25-46 grams and in the females from 25-48 grams. As there is such a close relation between the weight of a chick and the weight of the egg from which it was hatched it is to be expected that JULL & QUINN (1925) found with both Rhode Island Reds and with Barred Plymouth Rocks that there was no significant difference in the case of either yearling hens or pullets between the mean percentage male and female chicks weight of egg weight. It can be considered that the separation of the sexes of chicks at hatching time on the basis of weight is unreliable.

A theory has been put forward that there is a difference between the way chicks of different sexes will turn, when held in a certain position. The method is said to be in practice in Japan and to have been introduced into California in the commercial hatcheries there. If these differences do exist, there is no definite proof to indicate their reliability and it is probable that such expertness would be required that the method would be of doubtful/

doubtful value for the practical poultryman. From the scientific view point it might be worth while carrying out a psychological study of sexes during the first or second days of their lives.

MASUI (1927) reported a method was being used in Japan for distinguishing the sex of young chicks by the examination of the organs in the cloaca. In the cloaca of the male chick, a white body can be seen, which is absent from the female and it is claimed that Japanese girls are very expert at differentiating the sex of the young or day old chicks by this means. TOKYO (1928) further reviews the history of this discovery and gives a considerable amount of detail concerning the method.

On the suggestion of the writer and with his assistance, MISS HELEN N. MOLYNEUX, an advanced student at the National Institute of Poultry Husbandry, carried out a test of this so-called 'Japanese Method'. Two pens of birds were used; a pen of ten Barred Plymouth Rock hens mated with a Black Leghorn cockerel and a pen of three Cuckoo Leghorn hens also mated with a Black Leghorn cockerel. In addition, adult stock and all the available ducklings at the Institute were used for vent examination, 50 Single Comb White Leghorn chickens were used as controls. In all, there were 195 chicks examined and an effort made to determine their/

+ 1925
 (See also
 Paula Hedwig)

their sex at or near hatching time. Of these, 139 were from sex-linked crosses and could not be used for proving the accuracy of the crosses. The percentage accuracy with the 50 White Leghorns at one week of age was found to be 63.34 per cent and the percentage error 36.66 per cent. The male sexual organ described by MASUI (1927) & TOKYO (1928) was found to be present and to be plainly visible in the eleven weeks old chick and at earlier stages. It was found to be larger in the light breeds than in the heavier ones and was not discovered in capons. The sexing of day old ducklings by this method was simple and accurate but it did not appear from this preliminary experiment that the sexing of young chicks by using the presence or absence of the rudimentary male sexual organ was sufficiently accurate to be of economical importance. It was quite apparent that it would be a difficult and complicated method to learn, would take a relatively long time to sex a large number of chicks, and it allows much too great a pullet error.

DUNN (1923) reported preliminary tests by Prof. W.E. Warner of the Connecticut Agricultural College that indicated that the heart beat is much more rapid in the female than in the male. Using a stethoscope on day old chicks kept in a dark incubator to prevent excitement and rapid movement, he separated one/

one hundred chicks into lots of males and females with an accuracy of 91 per cent. No report is available of any attempt to employ this method commercially and it is apparent it has its limitations. **CARD** (1918) obtained no evidence to indicate that sex could be determined with anything like practical accuracy by observing the body temperature of chicks when hatched.

SEX RATIO.

DUNN (1923) quotes **PEARL** (1917) who reported under ordinary conditions a normal proportion of about 94 males to 100 females between the sexes of domestic fowls. **PEARL'S** figures were based on a study of some 22,000 chicks of known sex. **JULL** (1923) reported by **CREW** (1925) gave observations for three years on the sex of chickens hatched from eggs of 45 hens during their first year of production. The secondary sex ratio was found to be 48.71 expressed as a percentage. **CREW** (1925) states that "The sex-ratio varies in different matings and the disturbance seems to be related to the relative physiological condition of the parents at the time. In the experience of many poultry breeders, the first lot of eggs laid by a pullet yields a predominance of male chickens, whereas as/

as the season advances and the pullet ages, the proportion of males steadily decreases. MUSSEHL (1923) observed the sex of all chicks hatched from normal eggs incubated during February, March, April and May 1922 and found the sex distribution of 1514 chicks of the S.C. White Leghorn Barred Plymouth Rocks, and Rhode Island Reds. Of the 1514 chicks, 791 were males or 52.24 per cent. In the S.C. White Leghorns, 52.72 per cent of the chicks hatched were males; in the S.C. Rhode Island Reds, 51.16; and in the Barred Plymouth Rocks, 53.75 per cent. To get the influence of date of hatch, he divided all the chicks into two groups depending upon whether or not they were hatched before or after April 10th. The sex ratio for S.C. White Leghorns hatched before April 10th was 54.87 and after 52.11. For S.C. Rhode Island Reds the figures were 50.17 and 52.01 and for Barred Plymouth Rocks, 53.65 and 53.84. It can be seen from these figures that there was no difference in the Barred Rocks, a difference in favour of the females in the early hatched Rhode Island Reds and a higher male to female ratio in the early hatched White Leghorns. It is doubtful if any of these figures are significant. CALLENBACK (1929) found with Single Comb White Leghorn and with Barred Plymouth Rocks that there was no relationship between antecedent egg production and the sex ratio of chicks placed in the brooding quarters.

SEX-LINKED INHERITANCE IN THE DOMESTIC FOWL.

According to present indications, there are in the fowl 17 pairs of autosomes and in addition there are two sex-chromosomes in the male and ⁽²²⁾ one sex-chromosome in the female. ^(WZ) If these indications are correct, there are 35 chromosomes in the female and 36 in the male. It is with the sex chromosomes that one is concerned in dealing with sex linkage. When sex linkage is not involved, the genes are carried by autosomes. It makes no difference if the dominant gene of a pair is introduced through the sire or the dam. If, however, the genes are carried on the sex or z chromosome, there is a considerable difference in the result. If the male parent carried the dominant gene for a sex-linked character, and the female carried the recessive gene of the alternate character, all the progeny will exhibit the dominant character. If, however, the female carried the dominant gene for the sex-linked character and the male the recessive allelomorph, the male progeny will exhibit the dominant character and the female progeny, the recessive character. In poultry and in the current moth, *Abbraxas*, the female is said to be heterogametic while in *Drosophila* it is the male that has unlike germ cells.

PEARL (1931) states that silver and barring were/

were known to be due to sex-linked factors in the early days of mendelism and that breeders of **Sebright** bantams were aware of the results of sex-linkage long before mendelism.

According to JULL, however, CUSHMAN (1893) was probably the first to report sex linkage when, as a result of mating Indian game cockerels to Barred Plymouth Rock hens, he observed that the sexes could be separated at hatching; as the sons of this mating showed signs of barring while the daughters were mostly black and showed none of the barring characteristics. DAVENPORT (1906) stated "Both sexes inherit some qualities from the corresponding sex of each of the parent species. The males have a yellow foot like their mother, whereas the females have a willow foot like their father". He probably laid the foundation for sex-linked inheritance but, it was BATESON & PUNNETT (1908) & SPILLMAN (1908), however, who explained that this inheritance of the barring character rested on a sex-linked basis. Numerous other investigators including GOODALE (1909 & 1910), PEARL & SURFACE (1910), MORGAN & GOODALE (1912), FRATEUR (1914) & DUNN (1923) confirmed PUNNETT & SPILLMAN'S results and augmented it to a considerable extent. PUNNETT (1923) reported that only the type of barring sometimes termed "cuckoo" barring would sex-link with black/

black or non-barring and that the barring that characterizes breeds such as Campines or Pencilled Hamburgs is of an entirely different nature. The 'Campine' barring cannot be used in connection with sex linkage. He also demonstrated that silver and gold plumage characters would sex-link. Shank colour was shown to be sex-linked by DAVENPORT (1906) but it was PUNNETT (1923) who showed its practical application. LEFEVRE & RUCKER (1923) claimed that the spangled pattern was sex-linked but subsequent experiments failed to confirm their results. SEREBROVSKY (1923) reported late feathering as a dominant sex-linked character and WARREN (1925) showed in the case of the Single Combed White Leghorn and Black Jersey giant breeds that rate of feathering is carried on the sex chromosome. HERTWIG & RITTERHAUS (1929) discovered the non-black chicks from a cross between a Plymouth Rock and an Orloff fell into two groups, those with a darker and those with a lighter down and the lighter down is evidently a sex-linked dominant factor. The same workers (1930) discovered a second sex-linked factor, a dark occipital spot on an otherwise lightish head, which is claimed to be recessive to the clear light head without pigment in this region as shown by the Orloff-Spangled Hamburg cross. PEACE (1931) suggests an inhibitor for the dark spot is involved.

The/

The results of PUNNETT'S (1930) work which confirms that of GOODALE (1918) and HURST (1921) makes it practically certain that no sex-linked fecundity factor exists, although the field of research in this direction has been by no means exhausted.

PUNNETT & PEASE (1922) reported a new breed, the Cambar, that shows sex-linkage in the downs within the breed and recently have developed it in two varieties, silver and gold. PEASE (1931) states "The essential ingredient is the barring factor which is located in the sex chromosome. The Cambar cock has two doses of the barring factor and the Cambar female has only one". As a consequence, the male chick at hatching is relatively paler when compared with the female chick.

There are at present the following sex-linked poultry factors reported and authentic:

- (1) Silver ground colour of plumage and down as opposed to gold.
- (2) "Cuckoo" barring in plumage as opposed to unbarred plumage.
- (3) Certain forms of light shank colour as opposed to dark shank colour.
- (4) Slow feathering as opposed to rapid feathering.
- (5) Silky pigment inhibitor as opposed to silky pigment.
- (6) Dark head spot inhibitor as opposed to the presence of the dark head spot.
- (7) 'Light' down as opposed to darker down.

BABCOCK & CLAUSEN (1927) state that the results obtained with barring and black in poultry "are consistently/

consistently accounted for on the assumptions that the genes for these characters are borne on the Z-chromosomes and that the W-chromosome is merely a neutral mate of the Z-chromosome in the female. If B = barred and b = black, the following scheme will show how these assumptions work out:-

To test the economic value of the sex-linked
 barred female X black male
 P1 W(BZ) X (bz)(bz)

F1 black female W(bz) + (BZ)(bz) barred male.

F2 W(BZ) W(bz) (bz)(BZ) (bz)(bz)
 barred female black female barred male black Male

black female X barred male

P1 W(bz) X (BZ)(BZ)

F1 barred female W(BZ) + (bz)(BZ) barred male

F2 W(bz) W(BZ) (BZ)(bz) (BZ)(BZ)

black female barred female barred male barred male

The sex linkage of other factors in poultry can be assumed to take place in a similar way.

hatching.

When the chicks were examined at six weeks,

SOME SEX-LINKED CROSSES.

EXPERIMENT No.1. WHITE BRESSE x S.C. WHITE LEGHORN.

OBJECT:

To test the economic value of the sex-linked shank factor in this cross.

MATERIAL:

A S.C. White Bresse cockerel from a reliable breeder of standard bred stock was mated with eight S.C. White Leghorn hens from the breeding flock of the National Institute of Poultry Husbandry. The White Bresse have dark blue legs and feet and the White Leghorns have yellow legs and feet. The cross to be of economic value should give all chicks of the female sex with legs of a different colour at hatching from those of the male. The hens were trapnested and the chicks were individually pedigreed. Details of leg and plumage colour were noted and an effort made to 'sex' them at hatching.

RESULTS:

Eightyone chicks were hatched and reared to six weeks of age. Of these, 54 were correctly sexed and 27 were found to have been incorrectly sexed at hatching.

When the chicks were examined at one week,
it/

it was still not possible to satisfactorily tell the sex. At two weeks, more pullets and cockerels were recognizable, but there were still questionable ones. It was four weeks before they could be segregated with certainty. The pullets produced from the cross all developed the distinct blue colour of the legs similar to the sire.

The cockerels had white shanks, with few exceptions. One cockerel had shanks resembling the yellow colour of the dams. The shanks of seven of the fifty cockerels had a greyish appearance and one cockerel showed very definite dark blue legs at six weeks of age. The conclusion drawn from this experiment is that shank colour during the first few weeks of age is not sufficiently reliable in the case of this cross to make it of value commercially. This is now (1932) generally agreed by investigators and poultrymen.

ADDITIONAL OBSERVATIONS:

The pullets produced from the cross varied in plumage colour from pure white to barred grey and white plumage. Many of the pullets had splashed white plumage. The cockerels were nearly all pure white, a few showing signs of smuttiness. The brown eye colour of the Bresse was dominant to the reddish bay eye of the White Leghorn as all F1 offspring had brown eyes. Unfortunately it was not possible to follow up the case of the cockerels with yellow and with dark blue legs.

It/

It is of considerable scientific interest to note that most of the chicks start with yellow shanks and lose this yellow colour gradually up to the time when the true colour of the shank is visible. It has not been possible to find any reason for this phenomenon.

EXPERIMENT No.2. S.C. BLACK MINORCA x S.C. WHITE
LEGHORN.

OBJECT:

To test the economic value of the sex-linked shank factor in this cross.

MATERIAL:

A S.C. Black Minorca cockerel from a reliable breeder was mated to ten S.C. White Leghorn hens selected from the flocks of the National Institute of Poultry Husbandry. The Black Minorca has black or very dark slate legs and feet and the White Leghorn has yellow legs and feet. As in the case of the White Bresse White Leghorn cross, the cross to be of economic value should give all the female chicks with legs of a different colour at hatching from those of the male.

RESULTS:

There were 130 chicks hatched and examined from this pen. They all were more or less yellow in the leg at hatching time; the pullet chicks usually being/

being slightly less pigmented in the legs than the cockerel chicks. Complete records were obtained of 95 chicks at seven weeks of age or later when sex could be definitely determined. Of these, only 65 or (68.72 per cent) had been correctly sexed at hatching time. The 55 chicks hatched on April 25th were examined very carefully every few days and in the pullets it was noted that the blue pigment usually appeared first at the back and gradually appeared lower down the back. In a few cases, the pigment first appeared in the beak. The shanks of the cockerels slowly changed from yellow to white. From the observations made, less than half of the pullets could be identified at two weeks as to sex by their shank colour and only about ^htree-quarters of them were showing the shank pigment at three weeks old. By four weeks, comb and feathering as well as shank colour were sufficiently developed to make it possible to reliably tell the sex. At maturity, shank colour in the cockerels was white, with a few exceptions when blue pigment was present in spots or small patches. The shank colour in the pullets was dark blue except in the case of three pullets which had white shank colour. The conclusion drawn from this experiment is that the difference between the colour of the shanks in male and female chicks is not always distinct and that it is not sufficiently accurate to be of economic value.

ADDITIONAL/

ADDITIONAL OBSERVATIONS:

All the chicks from this cross with two exceptions, exhibited tails by the fourth or fifth day after hatching. The two exceptions were from the same hen. As late feathering chicks do not show tail feathers before three weeks, (WARREN, 1930) the F1 offspring were, except for these two chicks, rapid feathering and apparently the Black Minorca carries the rapid-feathering factor and is similar in this respect to the White Leghorn. There was no sex-linkage in eye colour. The down colour of the chicks was mainly white with black tickings, a few chicks being all white. At maturity, the cockerels were mostly white and the pullets white with a good deal of black feathering.

EXPERIMENT No.3. S.C. BLACK LEGHORN x BARRED
PLYMOUTH ROCK.

OBJECT:

To test the economic value of the sex-linked barred factor in this cross.

MATERIAL:

A S.C. Black Leghorn cockerel from a reliable breeder of utility stock was mated to a pen of eight Barred Plymouth Rock hens of the National Institute of Poultry Husbandry stock.

RESULTS/

RESULTS:

There were 142 chickens hatched and individually pedigreed as to sire and dam. In every case of sex determination at hatching, the sex was substantiated on re-examination when the chickens had taken on their adult plumage and developed their secondary sexual characteristics. At hatching, the male chicks were black with some white splashes on various parts of the body and in addition had a small white head-patch which varied to some extent in size. The pullet chicks were similar to the males but had no white head-patch: The adult plumage of the males was barred and that of the pullets was black. The cross proved the barred factor in this cross to be reliable for sex-determination.

ADDITIONAL OBSERVATIONS:

It was not possible to notice any difference in eye or shank colour in the sexes at hatching. At maturity, the pullets had somewhat darker eyes and shanks.

EXPERIMENT No.4 S.C. BLACK LEGHORN x S.C.
CUCKOO LEGHORN.

OBJECT:

To test the economic value of sex-linked barred factor within the Leghorn breed.

MATERIAL:

Two matings were made in subsequent years. S.C. Black Leghorn cockerels from a reliable breeder were used in both matings and they were of the same strain as those used in the Black Leghorn - Barred Plymouth Rock mating. The three Cuckoo Leghorn hens used in the first mating were from a breeder who believed his strain to be pure for the sex-linked barring factor. Only three hens were used in the first mating. In the second mating, two cockerels were mated to 39 Cuckoo Leghorn hens that had been reared on the plant of the National Institute of Poultry Husbandry but bred from hens purchased from the same Cuckoo Leghorn breeder supplying the three hens used in the first mating. The chicks were individually pedigreed and sexed at a day old and at seven weeks.

RESULTS:

From the first mating, only 31 chicks were obtained and only 25 of these were available for checking at seven weeks. Of the 25 chickens, 14 were correctly/

correctly sexed, a percentage of only 56. Two out of the three hens gave results similar to those obtained for the Black Leghorn - Barred Rock cross. The third hen gave mismarked chicks which could not be sexed accurately, including two all-black male chicks, a black pullet chick, a black male chick with a white head spot, grey and brown striped pullet chicks and grey and brown striped male chicks.

All the adult pullets, with the exception of the mismarked grey-brown chicks, were pure black and had black beaks, black legs with yellow toes, and eyes varying from dark yellow to dark brown. The pullets from the grey brown chicks were black with brown breasts and very yellow legs.

From the second larger mating, 250 chickens were obtained upon which observations were obtained at both hatching and at seven weeks. Of these 117 had black heads and 133 had light heads. Of the 117 having black heads 106 were found to be pullets and 11 turned out to be males. Of the 133 with white head spots 114 were males and 19 were females. The accuracy obtained with the head colour was therefore 90.59 per cent with the males and 85.71 per cent with the females. The incorrectly sexed chicks were traced to a few hens. A portion of these were, as in the first mating, grey and brown striped. It is apparent that these dams were impure for the 'cuckoo' barring factor.

A/

A number of them have been retained for further study.

BEAK COLOUR - A SEX-LINKED FACTOR.

In addition to head colour, observations were taken of the shank colour and the beak colour of all chickens. No relation was found between shank colour and the sex of the chickens, but a valuable discovery was made in connection with beak colour. Of the 250 chickens, 129 had black beaks and 121 had horn beaks. Of the chickens having black beaks, 118 were females and 11 males. Of the chickens having horn beaks, 117 were male and only 7 females. The accuracy obtained with the beak colour was, therefore, 91.47 per cent with the males and 94.21 per cent with the females. Again the inaccuracies were traced to a few females, which were apparently impure.

Using both factors, it was found that out of the 250 chickens observed that there were no pullet chickens with black heads and horn beaks and only 7 male chicks with that combination. There were 114 chicks with light head parts and horn beaks, only 7 of which were pullets. Of the 110 with black beaks and black heads only 4 were males. There were 19 chickens with light head parts and black beaks of which 12 were pullets/

pullets and 7 cockerels. There are, therefore, 4 male chickens with black heads and black beaks that would definitely be sexed wrongly and 7 that due to their black heads might have been inaccurately judged. This is an error of 8.8 per cent. There would have been 7 female chickens with light head points and horn beaks that would have been taken for males and 12 others, because of the spot on their heads, might, in spite of their black beaks, have been inaccurately sexed as males. This is an error of 15.2 per cent. If, on the other hand, all the chickens with horn beaks and - or light head spots were taken as males, only 4 mistakes would have been made and an accuracy of 91.6 per cent recorded. If alternatively, all the chickens with black beaks and - or black heads were taken as pullets, there would have been 25 mistakes or an accuracy of 90 per cent

EXPERIMENT No. 5. 3.0. BUCKEY'S ISLAND RED x 3.0. BROOD
 TABLE No. I.
 ISLAND RED.

SEX	BLACK HEAD	90	BLACK HEAD	90	LIGHT HEAD	90	LIGHT HEAD	90	TOTAL
	BLACK BEAK		HORN BEAK		BLACK BEAK		HORN BEAK		
MALE	4	1.6	7	2.8	7	2.8	107	42.8	125
FEMALE	106	42.4	-	0.0	12	4.8	7	2.8	125
TOTAL	110	44.0	7	2.8	19	7.6	114	45.6	250

Using the test of χ^2 distribution, $\chi^2 = \frac{1}{a+a'} (an' - a'n)^2$. As n and n' both equal 1, we have

$$\begin{aligned} \text{Black head} & \chi^2 = \frac{1}{110} (106 - 4)^2 = 94.58 \text{ and P is } .01 \\ \text{Black beak} & \\ \text{Black head} & = \frac{1}{7} (7-0)^2 = 7.00 \text{ and P is } .05 \\ \text{Horn beak} & \\ \text{Light head} & = \frac{1}{19} (12-7)^2 = 1.3158 \text{ and P is } .70 \\ \text{Black beak} & \\ \text{Light head} & = \frac{1}{114} (107-7)^2 = 88.59 \text{ and P is } .01 \\ \text{Horn beak} & \end{aligned}$$

and it is clear that light head and horn beak colour in this cross are associated with the male sex and the black head and the black beak with the female sex. Beak colour is therefore a sex-linked factor and was of as much value as head colour in sexing the chickens at hatching as the white head spot. Further work needs to be carried out in order to see the extent to which this discovery can be generally applied to crosses involving beaks of different colours.

EXPERIMENT No.5. S.C. CUCKOO LEGHORN x S.C. RHODE
ISLAND RED.

OBJECT:

To test the economic value of the sex-linked rate of feathering factor in this cross.

MATERIAL:

Four S.C. Cuckoo Leghorn cockerels with the same dam and sire were mated to eighty S.C. Rhode Island Red hens of the National Institute of Poultry Husbandry strain. The chicks were individually pedigreed and they were examined to endeavour to determine their sex as soon as they were dry.

RESULTS:

Records were obtained on 269 chickens of which 161 turned out to be pullets and 108 to be cockerels. Of the 161 pullets, 140 or 86.96 per cent were correctly sexed at hatching and of the 108 cockerels, 75 or 69.44 per cent were correct. There were 54 errors in sex determination at hatching out of the 269, or a percentage of 20.07.

The sexing at hatching by means of rate of feathering depends upon the appearance of either the tail feathers or the primary or secondary flight feathers. As the latter are the first to develop they are used in preference to the tail feathering. If
the/

the separation of the sexes is not made as soon as the chicks have fluffed out some difficulty is experienced in distinguishing the earliest hatched males which should have the shorter feathers from the latest hatched female chicks. The error in sexing chicks in this experiment was possibly due to occasionally leaving the chicks too long before sexing them and to the Rhode Island Red dams being heterozygous for slow feathering. This method of sexing shows considerable possibilities.

ADDITIONAL OBSERVATIONS:

The adult pullets were mainly cuckoo-barred but usually had gold or reddish gold hackles. The males were also cuckoo barred with gold or reddish gold hackle and saddle feathers. A few adult birds showed a considerable amount of white scattered through the plumage.

EXPERIMENT No.6/

EXPERIMENT No.6. BROWN SUSSEX x LIGHT SUSSEX.

OBJECT:

To test the economic value of the sex-linked Silver factor within the Sussex Breed.

MATERIAL:

Brown Sussex cockerels were purchased for use in the first mating and were raised at the National Institute of Poultry Husbandry plant for the second mating. The Light Sussex hens were all purchased from a pedigree breeder of utility stock. The chicks were not pedigreed. They were segregated for experimental feeding experiments at hatching time and handled fortnightly until eight weeks or more.

RESULTS:

966 chickens were observed in the first mating and 1470 as a result of the second mating of these varieties. The sexing of the chickens from the first mating was 100 per cent accurate. Amongst the pullets from the second mating, there were three silver birds which had been sexed as cockerels at hatching time. With these exceptions, the sexing was accurate. The chicks of the male sex at hatching had a creamy silver body and darker back and the ground colour of the down of the chicks of the female sex was golden brown.

The/

The cross proved in every way to be reliable from the point of view of sex determination. The adult males resembled the Light Sussex on a whole but showed in many cases a considerable amount of mahogany in the wing bows and back. The pullets varied in colour from brown to buff.

ADDITIONAL OBSERVATIONS:

As the three silver pullets mentioned above were possibly due to non-disjunction of the chromosomes they were reserved for further study and are the subject of PART IV. of this thesis.

Some of the cockerels with a very large amount of mahogany in the wing-bows and back were also retained.

In the first mating, some chickens showed up with five toes and also with four toes on one foot and five toes on the other. These were also retained and a study made of their inheritance of the polydactylous character.

EXPERIMENT No.7. S.C. RHODE ISLAND RED x
LIGHT SUSSEX.

OBJECT:

To test the economic value of the sex-linked Silver factor in this cross.

MATERIAL:

S.C. Rhode Island Red cockerels of known breeding were mated with eighty Light Sussex hens. Observations were taken as in EXPERIMENT No.6 and the chicks were not individually pedigreed.

RESULTS:

Observations were taken on 1348 chickens and were 100 per cent accurate. The chicks and pullets were similar to those from the cross in EXPERIMENT No.6. The cockerels were similar to the Light Sussex except that they were occasionally splashed with red.

ADDITIONAL OBSERVATIONS:

At one of the fortnightly weighings, a pullet was discovered by the writer with one leg white, as it should be, but the other leg mostly white but with a yellow streak down the back part of the shank and extending to the foot. This chimera is the subject of PART III. of this thesis. The occurrence of a number of yellow-shanked offspring indicated that some of the Light Sussex hens were apparently heterozygous for shank/

shank colour. Observations were taken on 1152 chickens at 8 weeks of age and 6.94 per cent were found to have yellow shanks. 559 chickens were males and of these the shanks of 7.33 per cent were yellow. 6.57 per cent of the 593 female chickens had yellow shanks.

S U M M A R Y.

In the experiments reported, the sex-linked factors studied included shank colour, 'cuckoo' barring, rate of feathering, and silver. The use of shank colour for sex determination did not prove of economic value. No difficulty was experienced in accurately determining sex at hatching with the Gold and Silver matings or with black and barring provided the females used were pure for the sex-linked factor involved. This probably holds true for rate of feathering as well. If varieties carrying dominant factors are to be used for sex linkage it is essential that they be pure for the sex-linked factor and breeders must in the future pay greater attention to the development of pure strains.

A new sex-linked factor, beak colour, is reported. Further experiments are required to determine the extent to which it can be applied to other than the cross involved.

Several cases of possible disjunction of chromosomes and a somatic mutation were observed.

PART III.

A LEG-COLOUR CHIMERA IN THE DOMESTIC FOWL
A POSSIBLE CASE OF SOMATIC MUTATION.

A Report in Support of the Main Thesis.

PART III.

A LEG-COLOUR CHIMERA IN THE DOMESTIC FOWL
A POSSIBLE CASE OF SOMATIC MUTATION.

A pullet having white shanks but with a yellow streak, apparently due to dermal pigmentation and extending down the back of the left leg from the hock to the bottom of the foot and including the entire bottom of the foot was discovered by the writer amongst the F 1 offspring of a mating of Rhode Island Red males with Light Sussex females. The spur on the left leg was yellow and slightly larger than the one on the right leg. There was no evidence of any other abnormalities in any part of the body.

KNOX (1931) mentions a pigment mutation from one of a series of crosses of Black Langshans with White Plymouth Rocks that had both shanks white, but one had a yellow streak. He termed the individual a colour chimera and tentatively suggested as the cause either a somatic gene mutation or non-disjunction. CREW(1932)discussed the occurrence of the KNOX chimera and/

and six somewhat similar cases; MACKLIN (1925). CREW (1928), LAMBERT (1929), all of which had been considered to be caused by either non-disjunction or gene mutation. SEREBROVSKY (1926) reports the development of exceptional feathers in certain crosses. He considered them to be due to some form of somatic segregation whereby some feathers get one set of genes and other feathers another set.

In explanation of the KNOX yellow-streaked leg case mentioned above, CREW postulates a loss of part of an autosome after the second cleavage division of the hen's egg. At the first cleavage division, two blastomeres are formed representing the right and left halves of the embryo. The second division results in the production by each of these two blastomeres of two others, one of which yields the anterior half of one side of the body, the other, the posterior half of the same side. Chromosome elimination at the first cleavage would yield dissimilarities involving the whole of two sides of the body. Chromosome elimination at the second cleavage would yield dissimilarities involving only the anterior or posterior regions of the two sides.

Since neither the whole side nor the whole of the anterior or posterior regions in the KNOX case or the writer's case are affected, the loss of chromosome material must necessarily have occurred at a still later/

later stage than the second cleavage, if CREW'S theory holds in these cases. Rhode Island Red X Light Sussex yellow streak chimera differs somewhat from the KNOX yellow streak mosaic. The Black Langshan has legs and feet that are blue-black, while the White Plymouth Rock has yellow shanks and feet. The shank colour of the Langshan is, according to PUNNETT (1923), due to epidermal pigment in the scales in addition to underlying pigment and sex-linkage^d with yellow shank colour. KNOX does not give the sex of his streaked leg-colour chimera. Presumably, the pullets of this cross would have blue shanks and the cockerels white shanks. His bird was probably a male. In the Rhode Island Red - Light Sussex cross, there is sex-linkage of plumage colour, but not of shank colour. It is expected, provided the females are pure for shank colour, that all the offspring will have white shanks. In the writer's opinion CREW'S hypothesis can be accepted as the most logical explanation of the yellow streaked chimeras with, however, the reservation that, in the Black Langshan - White Plymouth Rock case, the anomaly is due to loss of part of a sex chromosome and not an autosome as suggested by him, while in the Rhode Island Red X Light Sussex pullet described here the loss probably affects part of an autosome carrying the dominant factor for white epidermal pigment. The bird has been retax^med and/

and until the bird is mated, it is not possible to say whether the germ cells have been affected or not.

Judging from CREW'S (1932) results in mating a hen with legs of different colours, it would seem highly improbable that in the Rhode Island Red X Light Sussex case the bird's genetic constitution has been affected and it is provisionally assumed to be a chimera.

S U M M A R Y .

The presence of the yellow streak in the leg and foot of an F_1 pullet from the Rhode Island Red male X Light Sussex female mating is reported. It is the expression of a recessive autosomal character in a heterozygote and is probably due to a factor mutation in somatic cells during cleavage division so late in ontogeny that only the epidermal layer is affected.

PHOTO



A YELLOW STREAK ON A WHITE LEG.

PHOTO. The right leg of this RHODE ISLAND RED - LIGHT SUSSEX cross pullet is white as expected. The left leg has a streak of yellow extending from the hock to and including the entire bottom of the foot. The rest of the leg and foot is white. Such a condition might be due to factor mutation in somatic cells late in ontogeny.

PART IV.

A POSSIBLE CASE OF NON-DISJUNCTION
IN THE DOMESTIC FOWL.

A REPORT IN SUPPORT OF THE MAIN THESIS.

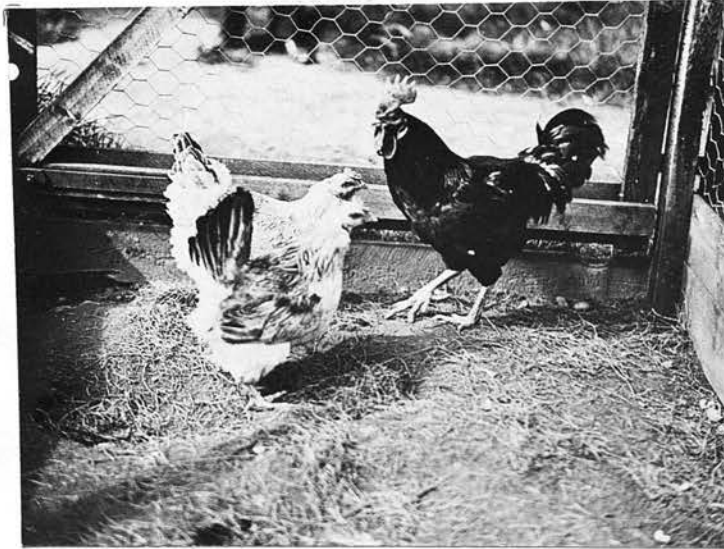
PART IV.

A POSSIBLE CASE OF NON-DISJUNCTION IN THE DOMESTIC FOWL.

INTRODUCTION.

Three silver females were observed in the offspring of the Brown Sussex x Light Sussex matings of 1930-1931. All the other females were gold in plumage. This mating involves the sex-linked characters silver and gold and normally all the F1 males are silver and all the F1 females are gold. If S = silver and s = gold and W = the determiner for female sex and the mate to the Z or sex chromosome, the following scheme will show how the sex-linkage of silver and gold in poultry normally works out and also the possible constitution of the silver females which occurred contrary to expectation.

FIG. I.



The BROWN SUSSEX MALE mated with two of the three
SILVER NON-DISJUNCTIONAL FOWLS.

ORIGINAL MATING.

P1	(<u>s Z</u>) (<u>s Z</u>)	x	<u>W</u> (<u>S Z</u>)	
	Brown Sussex Male	x	Light Sussex Female	Non-disjunction
F1	(<u>s Z</u>) <u>W</u>	(<u>s Z</u>) (<u>S Z</u>)	(<u>s Z</u>) <u>W</u> (<u>S Z</u>)	
	Brown Female	Silver Male	Silver Female	

The silver F1 females were mated to a Brown Sussex male.

The description of the birds in the mating is as follows:-

	MALE	FEMALES
HACKLE	Light mahogany striped with black	White with Brownish black lacing and white edging.
WING BOW	Rich dark mahogany	Buff, edges darker, with under colour blue grey.
BACK	" " "	Buff edged with dark brown.
WING COVERTS	Blue black	Darker at edges than wing bow.
PRIMARIES	Black, edged with brown	Brownish black, edged with white
SECONDARIES	" " " "	Brownish black, lighter than primaries, edged with buff.
BREAST	Black	Brownish white
TAIL	Blue black	Brownish black edged with buff.
THIGHS	Brown black	Brownish white.
UNDER COLOUR	Light grey	
BEAK	Horn	
EYES	Brown	
LEGS AND TOES	White	

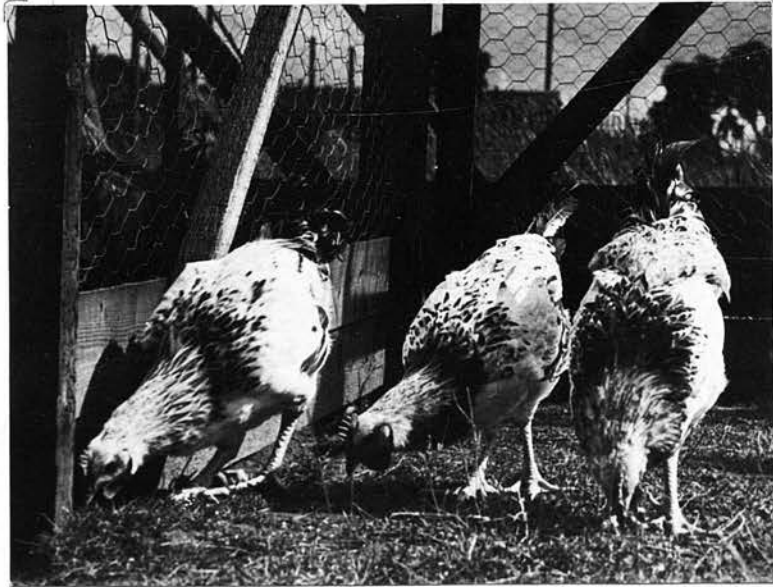
RESULTS.

Twenty-five birds were available for examination at 16 weeks of age. Of these, 7 males were silver, 7 males were gold, and 11 females were gold. There were no silver females observed. Some difficulty was experienced in making the classification at this age because of the mixture of various colours in the plumage. A description follows of typical silver and gold specimens obtained from the mating. A silver cockerel NO. 678 was hatched on March 17th. Its body colour was white with a black patch, its head white with a black spot, and its beak and legs were yellow. On April 28th, 1932, its body colour was black and white speckled, its hackle was columbian, its beak colour was horn and its legs were white. When examined on May 21st, it was black and white, with no mahogany, and with some light brown pencilling on the tips of the primaries and secondaries. Its hackle was columbian in pattern. On September 5th, 1932, it resembled a Light Sussex cockerel and was definitely silver in plumage.

Pullet NO. 328 was hatched on March 3rd, 1932.

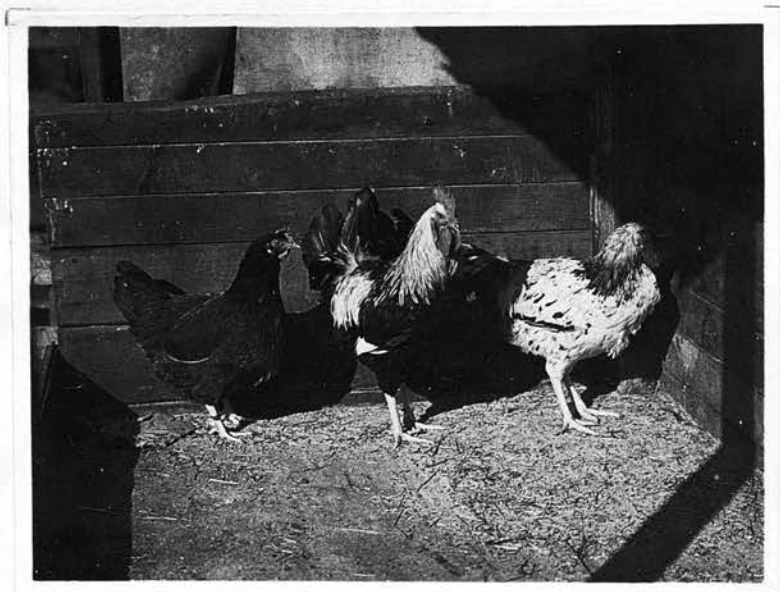
Its/

FIG. II.



Three SILVER COCKERELS from the mating FIG. I.

FIG. III.



Typical specimens of the three classes obtained:
SILVER MALE, GOLD FEMALE, and GOLD MALE.

Its body colour was dark brown or partridge, its head colour partridge and its beak and shanks were flesh-coloured. On April 28th, the body and head colour were unchanged but the beak and shanks were white. On May 21st, it was brown all over except for a red hackle ticked with black. On September 5th, it had a reddish orange hackle and otherwise resembled a typical Brown Sussex in plumage colour and in the colour of shanks and beak. It was definitely "gold" in plumage colour.

Cockerel NO. 1181 which was hatched on the 25th of March, 1932, and was creamy brown in body and head and had white beak and shanks. On May 2nd, its body colour was speckled brown and its head and hackle were columbian. On September 5th, its hackle and saddle were columbian in pattern with some black and brown present, its wing bows were mahogany laced with red, the wing coverts were mahogany tipped with white, the primaries and secondaries black tipped with brown, the breast and thighs were black and the under colour was slate. The beak was horn and white and the legs and toes were white. It had reddish bay eyes. It resembled its sire except for the columbian pattern in its hackle, wings and saddle. It was predominantly/

predominantly gold in plumage colour.

DISCUSSION.

There are several cases in poultry which have been recorded and described as instances of either non-disjunction or gene mutation [MACKLIN (1923), CREW (1928), LAMBERT (1929), KNOX (1931)]. CREW (1932) discusses these and a somewhat similar case and suggests that all of them may be regarded as examples of the loss of an autosome or a part of one.

These three silver hens from the gold-silver sex-linked cross can be explained on the basis of non-disjunction. BRIDGES (1916) explained similar breeding results in *Drosophila* on the basis of non-disjunction and cytological examination showed that an additional sex chromosome was present. In *Drosophila*, the male is heterogametic and the female is homogametic. In poultry, it is the female that produces unlike germ cells and the male that produces germ cells that are alike. BRIDGES (1916), however, quotes examples of primary non-disjunction in the male, as well as the female. MORGAN (1919) diagrams and describes the behaviour of non-disjunctive females in the sex-linked cross of *Drosophila* in/

in which red-eyed males are mated to white-eyed females. The results of the mating of the non-disjunctional pullets with a cockerel carrying the recessive factors can be explained on the same basis. If these silver hens are due to non-disjunction, one might assume that their constitution would be $(sZ)(SZ) W$. If in poultry, homo-synapsis (the pairing of the two Z-chromosomes) and hetero-synapsis (the pairing of a Z with the W) both occur, we have :-

NON-DISJUNCTIONAL FEMALES $(sZ)(SZ) W$.

HOMO-SYNAPSIS

HETERO-SYNAPSIS

$(sZ) (SZ) W$

$sZ W$

SZ

or

or

$SZ W$

sZ

Reduction
(Polar body) sZ SZ $sZ W$ $SZ W$

W

$sZ SZ$

Eggs SZW sZW SZ sZ

$sZ SZ$

W

The silver females were mated to a Brown Sussex male similar to their sire, and, assuming his constitution to be $(sZ sZ)$ the sperm would carry (sZ) and the expectation would be :-

Zygotes $(sZ SZ W)$ $(sZ sZ W)$ $(sZ SZ)$ $(sZ sZ)$ $(sZ sZ SZ)$ $(sZ W)$
Silver F Gold F Silver M Gold M Silver M Gold F

There/

There were 11 gold females, or 44 per cent, observed, 7 silver males, or 28 per cent, and 7 gold males, or 28 per cent. There were no silver females observed.

This probably was due to insufficient numbers. The three silver hens in the mating may be due to primary non-disjunction. In the light of our present knowledge it is a possible explanation for the results of the mating of the gold male with the silver females.

If non-disjunction had not occurred, there would have been no gold males produced :-

SILVER FEMALES SZW.

Eggs	<u>SZ</u>	<u>W</u>
Sperm	<u>sZ</u>	<u>sZ</u>
Zygote	<u>sZ SZ</u>	<u>sZ W</u>
	SILVER MALES	GOLD FEMALES

Therefore, assuming non-disjunction has taken place, if hetero-synapsis always occurred, which is exceedingly doubtful, no gold males would have been possible :-

SILVER FEMALES sZ SZ W.

Eggs	<u>sZ SZ</u>	<u>W</u>
Sperm	<u>s Z</u>	<u>s Z</u>
Zygote	<u>sZ sZ SZ</u>	<u>sZ W</u>
	SILVER MALES	GOLD FEMALES

If/

If we assume, that non-disjunction continues to occur, it is not possible to explain the presence of the gold females or the silver males :-

SILVER FEMALES sZ SZ W.

Eggs	<u>sZ</u>	(<u>SZW</u>)	
Sperm	<u>sZ</u>	<u>sZ</u>	
Zygote	<u>sZ sZ</u>	<u>sZ SZ W</u>	
	GOLD MALE	SILVER FEMALES	

If homo-synapsis always occurred, all four classes would have still been possible :-

SILVER FEMALES sZ SZ W

Eggs	<u>SZW</u>	<u>sZW</u>	<u>SZ</u>	<u>sZ</u>
Sperm	<u>sZ</u>	<u>sZ</u>	<u>sZ</u>	<u>sZ</u>
Zygote	<u>sZ SZ W</u>	<u>sZ sZ W</u>	<u>sZ SZ</u>	<u>sZ sZ</u>
	SILVER FEMALE	GOLD FEMALE	SILVER MALE	GOLD MALE

The numbers of each class would be expected to be equal.

The assumption has been made so far that the constitution of the silver females from the sex-linked mating was (sZ)(SZ) W. Until cytological evidence is available, the only basis for this assumption is/

is that gold males were obtained as well as the other two classes; silver males and gold females. The W factor must also be the determiner for female sex, and not indicate the absence of a sex chromosome. It must also be dominant to the male sex chromosomes. HANCE (1926) confirms previous evidence that the female is heterozygous and the male homozygous for the long (sex) chromosomes, but does not exclude the possibility of the presence of a Y, (or Z), chromosome in the female. GOLDSCHMIDT (1928) produced in the Gipsy-moth, in which the female is heterozygous for sex, what were actually females in spite of the fact that their genetic constitution (with two sex chromosomes) was that of males. He produced experimental proof that in dioecious animals, both sexes contained the determiners or genes for the production of either sex, and that the actual sex is determined by a quantitative relation or balance between these two sets of genes. Individuals, according to his conclusion of male genetic constitution (F)MM may be built up in which F comes from a race with high quantities of this gene and both M's from a race with a very small quantity of M. The result is a female in spite of male genetic constitution

GUYER (1930) stated that "Experiments and studies in sex determination and sex control all tend toward/

toward the conclusion that each sex in addition to its own determiners, also contains the genes for the production of the other sex. The actual sex of the individual is determined by the quantitative relations between these two sets of genes!

At present, it is assumed that a (Z W) individual is a female. If W represents a factor for femaleness and, as has already been accepted, it is dominant to the male determiner, it might be expected that it would be dominant over two male determiners, just as it would be expected that a (sZsZSZ) individual would be silver in spite of the two gold factors s and s.

A somewhat similar case to that under discussion is a gold cock from a poultry breeder using the Rhode Island Red Light Sussex cross. The bird was sent to Dr CREW at the Animal Breeding Research Institute, Edinburgh. It is various shades of red, has yellow shanks and would seem to be a case of non-disjunction. If so, it would be expected to have the constitution sZsZW in which case the assumptions made at the beginning of this paper are not correct. As Light Sussex fowls have white shanks, the dam of this gold cock must have been heterozygous for shank colour. If she was similar in constitution to the silver/

silver hens discussed here, that is, she was also heterozygous for the silver factor, sZSZW , the gold cockerel might be either sZsZ or sZsZsZ , probably the former. Cytological and genetic evidence is being obtained concerning his constitution. The suggestion is made, that, until the cytological evidence that is being obtained is available, the most logical explanation is that there is a dominant female sex determiner and that primary non-disjunction has occurred between the determiner and the Z chromosome carrying the dominant factor for silver.

Another possible explanation, besides non-disjunction, is inhibition. TAYLOR (1932) reported an inhibitor which, in the presence of sex-linked gold, produces a range of colour varying from reddish yellow to silver, depending upon the action of other modifying factors of gold. He suggested that the apparent dominance of gold over certain so-called silvers, which do not carry the sex-linked gene for true silver, might be explained in this way. The inhibitor acts as a simple recessive autosomal gene. If ig is the inhibitor and Ig is its dominant allelomorph, the following diagram illustrates the probable distribution of factors on this hypothesis and the results to be expected.

ORIGINAL/

In both the original and the F 1 matings, the inhibiting factor must come from both sexes to get silver offspring. The Brown Sussex males in the P 1 and F 1 matings were from different sources and unrelated, as far as is known. If either Brown or Light Sussex usually carry this inhibitor, it is difficult to explain why silver females from this sex-linked cross or Brown Sussex matings do not appear frequently. As has already been mentioned, only three silver females were observed in the 1470 F 1 offspring of Brown Sussex and Light Sussex matings examined.

In view of the assumption necessary, it seems possible, but not probable, that the explanation in the case of these silver females lies in the inhibiting factor for sex-linked gold.

A review of all possible autosomal factors, including recessive white possibly involved in the matings, fails to reveal any hypothesis in keeping with the results obtained. FIGURES 1, 2, and 3 illustrate the F 1 mating and some of the birds obtained.

S U M M A R Y

Three silver females from a sex-linked mating of a Brown Sussex male with light Sussex females were mated with another Brown Sussex male and three classes of offspring were obtained; silver males, gold males, and/

and gold females. Probably due to insufficient numbers, no silver females were recorded.

The results are provisionally explained on the basis of primary non-disjunction of a Z chromosome carrying the dominant factor for silver, and a dominant female sex determiner.

The possibility is discussed of an autosomal inhibitor for the sex-linked gold factor being the cause of the appearance of the silver females originally, and of the results of the subsequent matings.

P A R T V.

THE INHERITANCE OF THE REX FACTOR
IN THE RABBIT.

A REPORT OF EXPERIMENTS IN MULTIPLE FACTOR
INHERITANCE IN DOMESTIC RABBITS IN
SUPPORT OF THE MAIN THESIS.

In press: Journal of Heredity.

PART V.

THE INHERITANCE OF THE REX FACTOR
IN THE RABBIT.

The object of the experiment was to demonstrate the transmission of the "rex" character from a relatively new variety of rabbits to a well established utility breed. The Lilac normal-coated rabbit and the Castorrex were chosen for the experiment as, in addition to the rex factor, at least three known unit-characters for colour would be involved.

During the summer of 1929, a typical Castorrex buck was mated at the National Institute of Poultry Husbandry, to 14 typical Lilac does and 38 F1 individuals were obtained which were all wild grey or agouti in coat pattern and colouring. The mating inter se of selected F1 bucks and F1 does began in February, 1930 and by September 1931 records had been obtained of 524 F2 offspring from 9 bucks mated to 19 does.

UNIT-CHARACTERS.

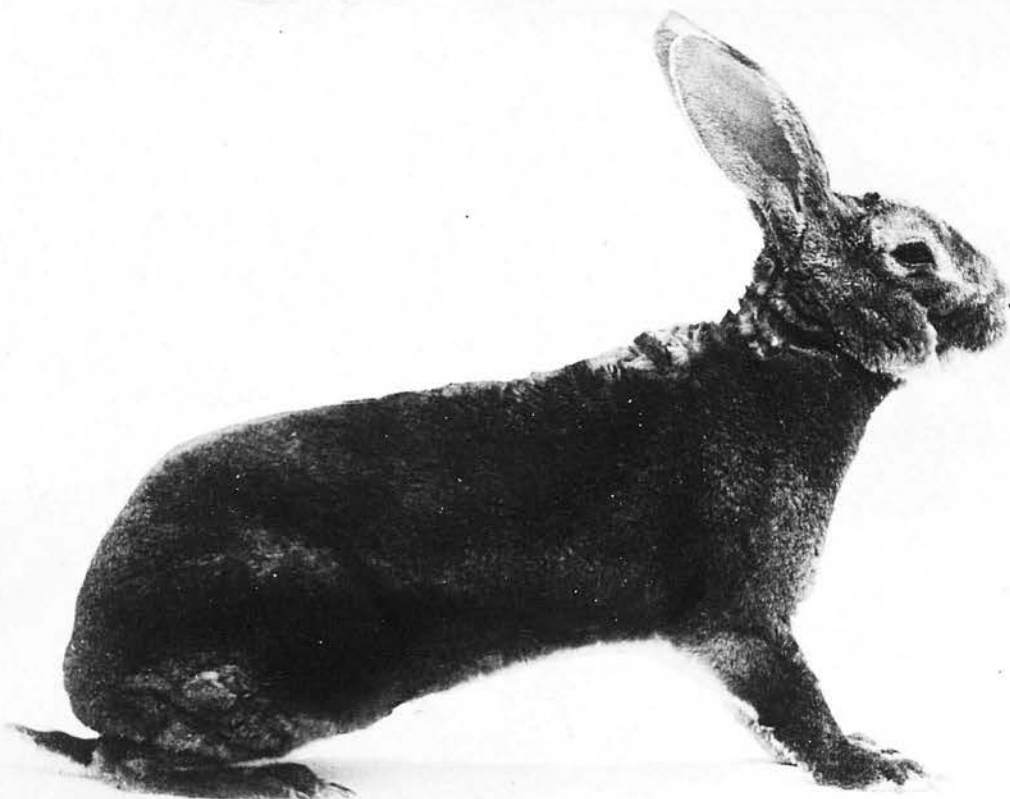
The "rex" character is recessive to normal coat and according to CASTLE (1) shows no linkage with any other mutant gene. Rabbits that are homozygous for this character have a mole-like coat due to the short hairs of fine texture which constitute it. The normal rabbit/

FIGURE I.

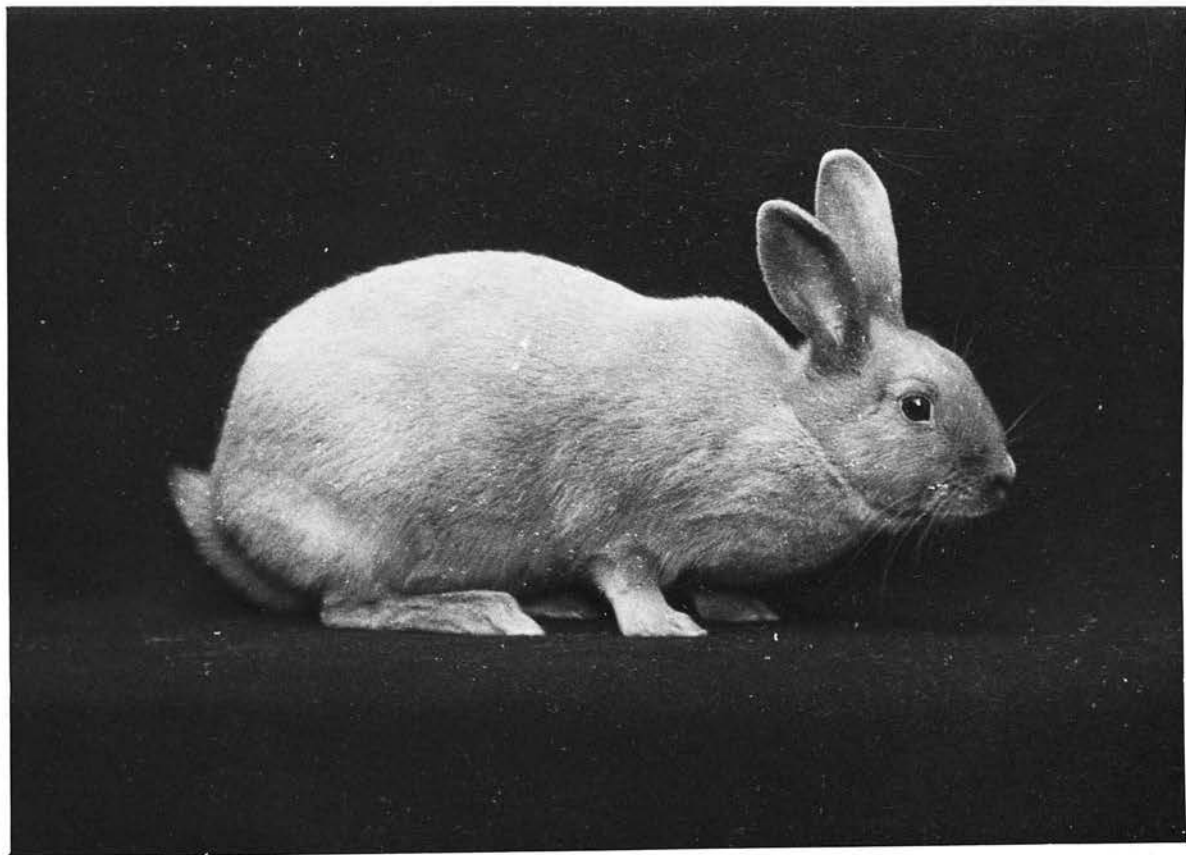
CASTORREX AND LILAC NORMAL RABBITS.

The upper photograph is of the Castorrex sire and the lower photograph is of the Lilac Normal dam of the parental generation. The Castorrex contains at least three dominant colour genes and a recessive coat gene. The Lilac normal has at least three recessive colour genes and one dominant coat gene.

PHOTOGRAPH NO. I. CASTORREX BUCK.



PHOTOGRAPH NO. II. LILAC NORMAL COATED DOE.



rabbit fur contains "guard" hairs that are relatively long and coarse and which in many cases are plucked from the skins before they are made into fur garments. The genetic formula for the rex character when homozygous is $r r$ and for the normal coat character $R R$. The "wild" or ordinary grey coat character is due to the presence of the dominant factor for Agouti (A). The alternative recessive concerned in this study is self (a). The agouti factor (A), when present in the zygote, turns the black character to agouti, blue to blue agouti, chocolate to chocolate agouti and lilac to lilac agouti. Selves have no band of yellow on the ordinary hairs of the coat or white tip to the hairs on under-surface; i.e. the belly and the underside of the tail.

Agouti rabbits, including the Castorrex, have a dominant factor (B) which causes the development of black and its alternative recessive is (b) which brings about a change from black pigment to brown (chocolate). In addition, there is a factor (D) present in the Agouti which in its recessive form is responsible for bringing about the dilution of colour. Blue is produced by diluting black, and lilac is the result of diluting chocolate. Expressed in another way, (D) is the factor which turns lilac into chocolate and B is the factor that turns it into blue. Lilac is a triple recessive/

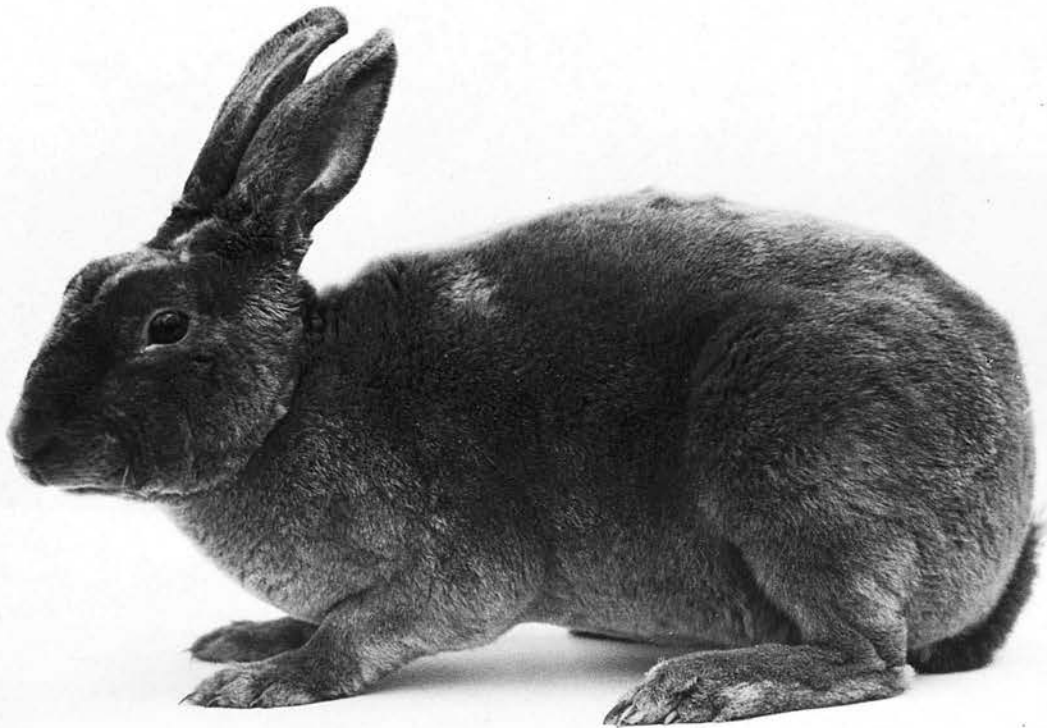
FIGURE II.

The first generation F1 animals are heterozygous for the three colour factors and the coat factor. The Lilac rex which has a theoretical expectation of 1 in 256 is recessive in four factors and will breed true, i.e. two Lilac rexes will, if mated give only Lilac rexes as offspring.

FI. CASTORREX x LILAC NORMAL.



LILAC REX.



Classes of F ₂ Animals.		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
		B D A R	B D a R	B d A R	b D A R	B d a R	b d A R	b b D R	b b D a R	B D A r	B D a r	B d A r	b D A r	B d a r	b D a r	b d A r	b d a r
81 Wild Normal	1	B D A R Wild															
27 Wild Rex	2	B D a R Wild Black															
27 Black Norm.	3	B d A R Wild Wild	Blue Agouti														
27 Blue Agouti Normal	4	b D A R Wild Wild	Wild	Choc. Agouti													
27 Choc. Agouti Normal	5	B d a R Wild Black	Blue Agouti	Wild	Blue												
9 Black Rex	6	b d A R Wild Wild	Blue Agouti	Choc. Agouti	Blue Agouti	Lilac Agouti											
9 Blue Agouti Rex	7	b D a R Wild Black	Wild	Choc. Agouti	Black	Choc. Agouti	Choc.										
9 Choc. Agouti Rex	8	b d a R Wild Black	Blue Agouti	Choc. Agouti	Blue	Lilac Agouti	Choc.	Lilac									
9 Blue Normal	9	B D A r Wild Wild	Wild	Wild	Wild	Wild	Wild	Wild	Wild	Wild							
9 Choc. Normal	10	B D a r Wild Black	Wild	Wild	Black	Wild	Black	Black	Black	Wild Black							
9 Lilac Agouti Normal	11	B d A r Wild Wild	Blue Agouti	Wild	Blue Agouti	Blue Agouti	Wild	Blue Agouti	Blue Agouti	Wild Wild	Blue Agouti						
3 Blue Rex	12	b D A r Wild Wild	Wild	Choc. Agouti	Wild	Choc. Agouti	Choc. Agouti	Choc. Agouti	Choc. Agouti	Wild Wild	Wild	Choc. Agouti					
3 Choc. Rex	13	B d a r Wild Black	Blue Agouti	Wild	Blue	Blue Agouti	Black	Blue	Blue	Wild Black	Blue Agouti	Wild	Choc. Agouti	Blue	Wild	Blue	
3 Lilac Agouti Rex	14	b D a r Wild Black	Wild	Choc. Agouti	Black	Choc. Agouti	Choc.	Choc.	Choc.	Wild Black	Wild	Choc. Agouti	Black	Choc.			
3 Lilac Normal	15	b d A r Wild Wild	Blue Agouti	Choc. Agouti	Blue Agouti	Lilac Agouti	Choc. Agouti	Lilac Agouti	Lilac Agouti	Wild Wild	Blue Agouti	Choc. Agouti	Blue Agouti	Choc. Agouti	Lilac Agouti		
1 Lilac Rex	16	b d a r Wild Black	Blue Agouti	Choc. Agouti	Blue	Lilac Agouti	Choc.	Lilac	Lilac	Wild Black	Blue Agouti	Choc. Agouti	Blue	Choc.	Lilac Agouti	Lilac	

recessive for colour containing the recessive factors
 (d). When B (black) and D (dense pigment) factors are
 together, they give black in the absence of factor (A)
 for agouti.
 The Castorrex rabbit has a genetic constitu-
 tion of rr AA BB DD i.e. it contains double doses of
 the recessive factors for rex and dominant factors for
 black dense pigment and agouti. The genetic
 of the Lilac normal-coated rabbit is shown by the
 formula RR aa bb dd i.e. it is homozygous for normal fur,
 non-agouti, chocolate and dilution of pigment. The
 first generation (F1) are all agouti colour

All the animals
 outside the red
 square have
 normal fur.
 The 64 animals
 inside the red
 square have
 Rex fur.
 Only one is Lilac
 Rex.

"wild" pattern and genetically are Bb Dd Aa Rr
 they are heterozygous for all four factors
 Chart No. 1. (attached) shows the genetic
 in the second (F2) generation
 classes of F2 animals according to the genetic
 expectation.

recessive for colour containing the recessive factors for agouti, black and dense pigment. The addition of black factor (B) to lilac produces blue instead of black because of the presence of the dilution factor, (d). When B (black) and D (dense pigment) factors are together, they give black in the absence of factor (A) for agouti.

The Castorrex rabbit has a genetic constitution of rr AA BB DD i.e. it contains double doses of the recessive factors for rex and dominant factors for black dense pigment and agouti. The genetic make-up of the Lilac normal-coated rabbit is shown by the formula RR aa bb dd i.e. it is homozygous for normal fur, non-agouti, chocolate and dilution of pigment. The first generation (F1) are all agouti colour, have the "wild" pattern and genetically are Bb Dd Aa Rr; i.e. they are heterozygous for all four factors.

Chart No.1. (attached) shows the distribution of gametes in the second (F2) generation and also the classes of F2 animals according to the theoretical Mendelian expectation.

TABLE NO.I.

TABLE NO. I.
RESULTS SECURED IN F2 GENERATION OF INTER SE
MATINGS OF CASTORREX X LILAC NORMAL FL'S.

COLOUR GROUPS	NORMALS		APPROX. DIFFERENCES		REXES		APPROX. DIFFERENCES		TOTALS		APPROX. DIFFERENCES
	EXPECTED	ACTUAL	EXPECTED	ACTUAL	EXPECTED	ACTUAL	EXPECTED	ACTUAL	EXPECTED	ACTUAL	
Agouti	165.79	190	+ 24	44	55.27	44	- 11	234	221.06	234	+ 13
Blue Agouti	55.27	62	+ 7	16	18.42	16	- 2	78	73.69	78	+ 4
Black	55.27	42	- 13	16	18.42	16	- 2	58	73.69	58	- 16
Blue	18.42	15	- 3	5	6.14	5	- 1	20	24.56	20	- 5
Chocolate Agouti	55.27	52	- 3	11	18.42	11	- 7	63	73.69	63	- 11
Lilac Agouti	18.42	31	+ 12	7	6.14	7	+ 1	38	24.56	38	+ 14
Chocolate	18.42	21	+ 2	3	6.14	3	- 3	24	24.56	24	-
Lilac	6.14	7	+ 1	2	2.05	2	-	9	8.19	9	+ 1
TOTAL	395.00	420	+ 27	104	131.00	104	- 27	524	524.00	524	-

TABLE NO.I shows the number of animals of each of the eight colours expected and actually obtained, the number of each that were expected to be normal-coated and rex-coated, and the results of the experiment. The number of rexes, and also the number of black normal rabbits obtained were significantly less than expected. The differences in the chocolate agouti and lilac agouti classes may be partly due to mistakes in identification because of their similarity. A number of animals included in the rexes had a condition of partial furlessness, which may be partially lethal and is probably, like most other forms of furlessness, recessive. As the abnormally low ratio of rex to normal is in agreement with other workers and general observation of practical breeders the most probable explanation is a higher prenatal death rate of rex rabbits. The explanation for the significantly low ratio of actual to expected numbers in the black normal animals is probably insufficient numbers of offspring.

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A C K N O W L E D G E M E N T S .

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A C K N O W L E D G E M E N T S.

The writer gladly acknowledges the advice and assistance given him in the experiments conducted and in the preparation of reports.

PART I.

Data on which the nutritional and management studies are based was obtained with the co-operation of various members of the staff of the National Institute of Poultry Husbandry. Assistance was rendered in the statistical analysis by Mr. F.J. DUDLEY M.A. Dip. Agric. (Cantab). In the physiological studies, Dr. MARIE GUTOWSKA with her advice and Dr. L. MUSKAIA by her her assistance in testing materials used, were most helpful. The hormone substances used were donated by LUDWIK SPEISS I SYN, Warsaw, Poland and E.R. SQUIBBS & CO. U.S.A.

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PARTS/

PARTS III AND IV.

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