EYEL PRODUCTION AND EGG FORMATION IN
THREE SMALL-BRED STRAINS OF CHICKENS.

A Thesis
Presented in Partial Fulfillment of the Requirements
for the Degree of Master of Science

by
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Approved by

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<td>1. Follicular Maturation in the Birds of the Three Populations</td>
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Evidence from previous research indicates that the genetic control over body and egg size may greatly affect rate of laying. The control of egg size appears to be at the level of the ovarian follicle of each female. Rate of egg production in small females may be limited by the supply of lipid (lipoprotein). Lipoprotein is a conjugated protein synthesized in the liver and transported through blood to the ovary for yolk formation. One limitation on the supply of lipoprotein is the size of the liver which is highly correlated with the size of the female.

It could be theorized that when the supply is limited, fewer ova undergo rapid development rather than a reduction of ova (yolk) size much below that characteristic of each specific female. When the genetic size of the mature ova is very large producing, for example, a 70 gm egg and the adult body size is small, 1 kg for example (as was observed in two dwarf pullets on our farm), the supply of lipoprotein for yolk formation greatly reduces rate of ovulation until it ovulates on alternate days. In other words, rate of lay may be limited by the supply of lipoprotein sufficient enough to satisfy the genetic and environmental egg size of the female. The theory stipulates that daily ovulations are possible if the genetic egg size of the pullet weighing 1 kg was greatly reduced to 40 gm, as an example. Further reduction of mature body size to that of the bantam, about 600 gm, could again reduce ovulation rate to very short sequence. Such small
females would not be able to produce enough lipoprotein to satisfy their egg weight demand of 40 gm or more per egg and lay more frequently than once every 48 hours.

There is a large amount of circumstantial evidence to support the theory that rate of ovulation is controlled by the balance between "genetic" egg size and the supply of lipoprotein in the circulation. Large broiler-type pullets appear to produce too much lipoprotein and often ovulate more than one mature ovum per day (Clancy and Jeep, 1968), even though their egg weight may approach 70 gm. The minimum body size for most rapid rate of lay of 60 gm eggs appears to about 1.8 kg (Rendom Sample Test, 1971). The genetic correlation between egg size and rate of lay is very low for egg-type chickens having mature body weight between 1.8 and 2.5 kg (Kinney, 1969). Dwarf egg-type pullets laying extremely large eggs seldom produce the second egg without missing a day (Butt, 1959 and Jeep, 1971). Conversely, pullets weighing 1.5 kg at the onset of lay produce much larger eggs, nearer their adult equivalent, when they are allowed more time for lipoprotein production by extending the daily light plus dark period to 27—rather than the normal 24-hour day (Morris, 1973).

The relationship described above involves many phenomena occurring mainly in the internal, physiological environment (histological and anatomical) as well as external environment (husbandry). To test these relationships (hypotheses) an experiment was designed with the following objectives:
1. To quantify the effect of body size on the supply of lipoprotein (lipids) available for yolk production.

2. To identify the relative importance of mature follicle size and body size as factors affecting rate of lay.
LITERATURE REVIEW

EFFECT OF SEX-LINKED DWARFING (dw) GENE ON VARIOUS ECONOMIC TRAITS:

The inferior feed efficiency of the larger broiler dams and the reduction in number of chicks produced which resulted in increased cost of production of broiler chicks has increased the possibility of using the sex-linked dwarfing gene, dw, in commercial broiler production.

Hutt (1949) was first to describe a type of dwarfism in chickens caused by a sex-linked recessive gene, dw, where the chicks grow normally to adults without any apparent abnormality. Since the time of Hutt (1949), who studied the effect of dw gene on various economic traits, there have been many studies on body weight, egg production, egg weight, sexual maturity, fertility, hatchability and viability. Some of these have been summarized in Table 1.

In addition to these there have been many studies on other characteristics like embryonic growth, egg quality, and carcass characteristics which will be reviewed subsequently.

BODY WEIGHT AND SHANK LENGTH:

Lerner (1945) found a correlation of .75 between 20-week body weight and shank length in a line of White Leghorns selected for shank
Table 1

Estimates of Dwarf (dw) Gene Effects in Females of Egg Production Strains

<table>
<thead>
<tr>
<th>Fertility &amp; Visc-</th>
<th>% Change Attributable to dw Gene#</th>
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<tr>
<td>Hetchability</td>
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<td>Body Weight</td>
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<th>Gene as normals</th>
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<td>-15.3</td>
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<td>Tulloni (1972)</td>
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#Percent reduction in the trait of a cross carrying the dwarf gene compared to a reciprocal cross or a closely related non-dwarf.

I S U: Iowa State University (From French, 1971).
length and a correlation of .79 between 36-week body weight and shank length. He stated that maximum shank length was achieved at 20 weeks of age, but the maximum correlation was not reached at this age. He interpreted this as evidence that skeletal size was indeed the limiting factor in body weight increase at least prior to the period of extensive fat deposition.

Morris et al. (1966) reported a correlation of .703 between shank length and skeletal weight and stated that shank length should give a good estimate of body size. Nordal and Briggs (1967) went to the extent of stating that shank length would be a better single measure of size than body weight. Telloni (1972) found positive and significant correlations of .66 and .64 between body weight and shank length for birds weighing 1700 gm (16) and 1180 gm (13), respectively. Further the corresponding regressions of body weight on shank length were 40.84 gm and 31.78 gm per mm increase in shank length. Atkinholle (1974) found a correlation of .68 between body weight and shank length in 95 dwarf type chickens weighing 760 gm at 52 weeks of age. The regression of body weight on shank length was 22.4 gm per mm increase in shank length.

BODY WEIGHT AND EGG WEIGHT:

Most poultrymen know that small hens tend to lay small eggs. This relationship was first expressed numerically by Asmundson (1921), who found a correlation of .584 between egg weight and adult body weight in White Leghorns. It is known that this relationship persists
after both egg weight and body weight have become maximum, for Atwood and Clark (1930) found the correlation between these traits to be .456, .434 and .426 in the first, second, and third years of laying. However, Marble (1931) showed that this relationship between egg weight and body weight is not a linear one. That is, this relationship can be expressed more accurately by the correlation ratio, biggest birds do not lay proportionately bigger eggs. Waters (1937) found that maximum adult egg weight was obtained when the bird reaches maximum adult body weight around 40-64 weeks.

Hutt (1959) studied this relationship between body weight and egg weight in dwarf and normal hens and concluded that egg size does increase with body size but not directly, and that smaller birds tend to lay eggs that are large in relation to body size, whether they carry 

\[ \text{DW} \] gene or not. Kinney (1969) summarized the phenotypic correlations between pullet body weight and pullet egg weight as .34 and between mature body weight and mature egg weight as .36. Fred-Home and Merat (1969) indicated that egg weight and body weight in dwarf pullets are more closely related than in their normal sisters.

Talloni (1972) found phenotypic correlations of .47 and .56 between body weight and egg weight for D6 and D3 populations at 50 weeks of age. However, the regressions of body weight on egg weight were not significant. Akinkugbe (1974) found a correlation of .59 between body weight and egg weight in a population (D5) having a 52-week mean body weight of 760 gm.

The above two mentioned references seem to confirm the indication of Fred-Home and Merat (1969) that body weight and egg weight are more
closely related in smaller pullets than in their normal sisters.

BODY WEIGHT AND EGG NUMBER:

Various investigators have studied the possibility of using body weight as an indication of the production capacity of a bird. These were mainly based on the relationship studies between body weight and egg number, some of which were positive and some negative, so small as to indicate little relationship.

Platt (1927) reported the relationship between body weight and egg number as nonlinear and that the smaller birds within a breed do not lay as well as the larger ones and the extremely heavy hens also tend to lay fewer eggs.

Batt (1949) reported that birds with extreme body weights do not lay as well as the intermediates. Kinney (1969) summarized the correlations between body weight and egg production at 46 weeks of age as .03. He listed a correlation of .01 between the pullet body weight and short term production.

Dickerson and Hughes (1964) reported that egg production declined 5 to 10 eggs per pullet housed for each one-tenth of a pound that hens were below an optimum body weight.

According to Jaap (1971) there appears to be two thresholds to body size reduction insofar as egg production is concerned. When minimum egg size is maintained at about 60 gm level, rate of lay appears to be sharply reduced if adult body size falls below 2 kg. When no attention is paid to egg size it appears possible to quantitatively reduce adult body size to about 1 kg before rate of lay is
seriously reduced. He found that when adult body size approached that
of the Bantam, namely in the 400-700 gm range females in the F2 and
F3 from the Bantam × Leghorn cross had very low rates of lay.

DuPlessis and Erasmus (1972) found a significant quadratic
regression between total egg production and weight at sexual maturity.
They concluded that a body weight range of 1.59 to 1.82 kg at sexual
maturity is the optimum weight for efficient egg production in the
first year. Further they found that 2.04 kg is the optimum mature
body weight in White Leghorns for maximum egg production and there was
a decline of 1½ eggs for every .23 kg increase in body weight. However,
they stated that at a body weight of 1.36-2.27 kg the correlation between
egg production, egg weight, and body weight was positive becoming nega-
tive when the birds weighed more than 2.27 kg. Merat (1969) obtained a
significant correlation of .56 between body weight and egg number in a
population of dwarf chickens. Further, he reported a significant
partial correlation of .53 between body weight and egg number with egg
weight as constant.

Tolloni (1972) found nonsignificant correlation of -.16 and .05
between body weight and egg number in the birds of two populations, D6
and B5, at 50 weeks of age. Akinkuolle (1974) found a significant
correlation of .62 between body weight and egg number in a population of
D5 chickens at 50 weeks of age. Further, the partial correlation of .49
between body weight and egg number with fixed egg weight was significant.
EGG WEIGHT AND EGG NUMBER:

Egg weight is the second most important trait after egg production within any strain of chickens in both layer and broiler production. There have been many studies to find the mode of inheritance of egg weight and its relationship to egg production.

Blyth (1952) found that birds with very high, or very low, rates of production laid smaller eggs. However, Wyatt (1974) showed a slight positive correlation between egg weight and egg production.

Kinne (1969) summarized the reported estimates of phenotypic correlations for various traits of chickens. He listed a correlation of .04 between pullet egg weight and production from 34 to 64 weeks of age, but 0 for short term production.

Maret (1969) obtained a nonsignificant correlation of .26 between number of eggs and egg weight in a population of dwarf chickens. Telloni (1972) found a small and nonsignificant correlation between egg weight and egg number in small boded hens. Singh et al. (1972) reported a correlation coefficient of -.11 between egg weight and egg number in a White Leghorn population.

EGG WEIGHT AND YOLK WEIGHT:

About 52% of the egg weight is attributable to yolk weight. It is known that either direct mechanical stimulation of yolk in the oviduct or some chemical substance diffusing from the yolk would cause secretion of albumen by the magnum portion of the oviduct in the hen (Gilbert, 1971). Thus, yolk can influence the size of an egg to a great extent.
Various investigators have reported phenotypic correlations between egg weight and yolk weight ranging from .820 (Jull, 1928), .556 (Asmundson, 1933), .593 (Jaffe, 1954) to .64 (Singh et al., 1972).

Earlier, Scott and Warren (1941) presented evidence that composition of the egg was influenced by egg weight. Asmundson (1933) reported that yolk weight expressed as percent of total egg weight increased with the age of the layer. Similar reports have been made by Cunningham et al. (1960), Kline et al. (1965), and Marion et al. (1966). However, within an age group there is a significant negative relationship between percent yolk and egg size (Marion et al., 1964). This confirms an earlier report by Yao and Skinner (1959) who found a negative and significant correlation of -.36 between yolk percentage and egg size. Marion et al. (1964) further, found that yolk decreased and albumen increased by 3% for each 10 gm increase in egg size and concluded that variation in proportionate parts of an egg is caused mostly by physiological changes associated with aging and environmental effects.

Tolman and Yao (1960) studied the effect of crossbreeding on yolk size in three breeds, two strains of White Leghorns and their crosses in chickens at twelve months of age. They found highly significant differences between the lines, sires, dams and between the crosses in egg yolk size. They also found heterotic effect in the crosses between different breeds.

Neret (1972) compared the quantity of yolk and albumen in relation to total egg weight between dwarf and normal chickens and...
concluded that the gene does not modify the relative proportion of yolk and albumen.

**GENETIC CORRELATIONS BETWEEN EGG WEIGHT AND YOLK WEIGHT:**

The reported genetic correlation coefficients between egg weight and yolk weight have also been high. Jaffe (1964) reported a genetic correlation of .82 based on sire and dam components of variances in a population of commercial White Leghorns at 32 weeks of age. Singh et al. (1972) reported a genetic correlation of .79 ± .09 between egg weight and yolk weight in a closed White Leghorn population.

**HERITABILITIES OF EGG WEIGHT:**

Loose (1949), and Lerner (1950) defined heritability as the portion of the total variance within a population which is directly due to genetic differences.

Wyatt (1954) reported heritabilities of .52 and .58 for March egg weight obtained by sire and dam components of variances and by offspring on parent regression technique. There have been many reports which have reported similar estimates of heritabilities for egg weight varying from .45 to .51 based on the sire and dam components of variances: (Dickerson, 1957), (Fuchs and Kreuger, 1957), (Sticks, 1958), and (Yeo, 1958).

Kinney (1959) summarized the reported estimates of heritabilities for mature egg weight as .49 based on sire and dam components of variances in White Leghorns.
HERITABILITIES OF YOLK WEIGHT:

Scheinberg et al. (1955) estimated heritabilities ranging from 0 to .12 for yolk weight in three breeds of chickens. He attributed this low estimate of heritability for yolk weight to genetic differences due to dominance and epistasis. However, other reports on heritability for yolk weight which are slightly higher than the report of Scheinberg et al. have been made, .35 by Yao and Skinner (1959), .45 ± .12 by Jaffe (1964) and .35 ± .21 by Singh et al. (1972).

BODY WEIGHT AND LIVER WEIGHT:

The liver weight between 2 and 4% of the body weight according to Hafez (1955), Al-Debagh, and Abdulla (1963) and Boldizer and Kasma (1968). They have investigated various developmental features including the relative size of the liver with age or increasing body weight. Hafez (1955) found that birds weighing 1.0 kg and the every just starting to function at seven months of age had livers weighing 35 gm. When the birds were twenty-seven months old and weighing 1.4 kg, livers were weighing 55.6 gm, which was about 4% of the body weight.

Francis et al. (1968) did not find any significant strain differences in liver weight related to body weight in three strains of White Leghorns.

Deghir and Pellett (1967) measured the body and liver weights in three different breeds and two breed crosses over an age range of 0-8 weeks. They found a correlation of .81 to .96 for all ages in these young birds and significant regressions of .0219 gm to .0318 gm increase
in body weight. Further, they found that faster-growing breeds had lower ratios of liver weight to body weight and higher correlations between body weight and liver weight ratios. The correlation between body weight and liver weight ratio was negative and significant.

Frankham and Doornenbal (1972) compared two lines of White Leghorns selected for egg production and early maturity to the parent group and found that the birds of selected line had significantly lower body weights compared to the control parent group at 440 days of age. However, the liver weights of the selected lines were significantly larger than the control group at the same age. Further, they did not find any significant difference in the liver weights between the select and control groups on the day they laid their first egg. This seems to show that liver assumes a leading role during the production phase and that larger livers may be essential for increased lipoprotein synthesis, which in turn may have a significant effect on rate of lay. Further, they found a significant regression of liver weight on body weight of .0257 gm per unit increase in body weight in the selected lines at 440 days of age.

ROLE OF LIVER IN LIP undermined: It is generally accepted that the synthesis of yolk proteins and lipids takes place in the liver (Gilbert, 1971). The implication that the liver is involved in the production of yolk precursors was supported by the early isotopic experiments of Hovey and Hahn (1953), which suggested that the liver was the site of formation of yolk phospholipid. Flickinger and Rounds (1956) subsequently showed that P32 was
incorporated into the phosphoprotein of liver before it appeared in the plasma and ultimately in the yolk.

Lorenz et al. (1958) showed that the liver of the laying hen contained twice the concentration of lipid found in that of immature birds, and that this was largely, if not entirely, due to an increase in triglyceride. Czepko et al. (1941) demonstrated that increase of liver lipids is shown by increase in liver weight as the bird approaches sexual maturity and that it is preceded or coincided with the increase in liver lipids. O’Hea and Leavelle (1968) and Leavelle (1969) studied the relative importance of liver in lipogenesis and concluded that liver is the main site of fatty acid synthesis in chickens in contrast to the dominant role of adipose tissue in mammalian lipogenesis.

LIVER LIPIDS AND THEIR RELATION WITH ECONOMIC TRAITS:

Lorenz et al. (1958), who studied liver lipids in relation to egg production (100 days) and number of actively-growing yolks in the ovary, did not find any significant correlations between them.

The lipid content of liver is very much dependent upon feeding and management. Leavelle and Bray (1970) reported a liver lipid content of 43.8 ± 4.1% on percent dry liver weight basis in a control group of White Leghorn which had been in production for five months.

Wolford and Folin (1971) fed a diet containing 3.6 Kcal metabolizable energy and .172 gm protein per gm of feed to White Leghorn birds. The birds were fed restricted for six weeks and fed ad libitum for the next eight weeks. They found a high correlation of .544 between
liver lipid and body weight. Some of these birds had a lipid content as high as 48.5% on dry liver weight basis without any signs of liver hemorrhage or any signs of fatty liver syndrome.

Paulsfox and Fliegel (1971) fed 16% protein with 0 to 6% levels of tallow to White Leghorn pullets from 20-74 weeks of age. They found no significant correlation between liver lipids and total plasma lipids.

Thayer et al. (1973) found liver lipid on dry weight basis ranging from 10 to 35% in laying birds from 22-58 weeks of age. They indicated that accumulation of liver lipids was not entirely time dependent nor did it seem to be closely related to level of production.

Schramm and Griffith (1973) fed a basal diet containing 3073 calories of metabolizable energy and 15.87% protein to a control group of commercial White Leghorn birds. They found liver lipids on dry weight basis as high as 53.8-56.6% at 20 weeks of age and 58.8% at 64 weeks of age.

Garlich et al. (1974) reported average lipid values ranging from 25.8 to 49.0% on a dry weight basis in twenty varieties of 71-week-old laying hens managed in three confinement systems. They found a correlation of .440 between liver lipid and body weight in hens confined two per cage. However, they did not find any significant correlation between liver lipid and egg production.

PLASMA LIPIDS AND THEIR RELATIONSHIP TO RATE OF LAY

The egg yolk lipids are derived from circulating plasma lipoproteins which are synthesized in the liver in response to the hormonal changes which accompany the onset of lay (Gilbert, 1971).
Lorenz et al. (1937) reported that in the mature female bird actively engaged in egg laying, the lipid concentration of the blood is enormously increased above that of the immature female. They further indicated that the rise in the lipid level of the blood is related to ovarian activity, for it first appeared in female birds during puberty and at no time occurred in the male bird from early age to maturity. However, they did not find any correlation between the raised lipid level and duration or intensity of egg production, indicating that the degree of ovarian activity does not determine the concentration of lipids in the blood.

Heald and Redman (1965) indicated that the changes in the plasma lipid are greatest 1½ days preceding egg laying when the values for plasma Free Fatty Acids (FFA) may increase from between 0.2 and 0.5 meq/lit to 4.0 meq/lit and total plasma lipids from 0.2 to 0.5 gm/100 ml to 10 to 14 gm/100 ml (McIndoe, 1959). When the laying starts, the plasma FFA has been found to fall sharply to between 0.75 and 1.5 meq/lit (Heald and Redman, 1965), and the total lipids to between 1.5 and 3.0 gm/100 ml.

Weiss and Fisher (1957) measured the amount of plasma lipid by turbidimetric method in White Leghorns at 56 weeks of age and found a plasma lipid level of 1.37 gm/100 ml plasma. They found a significant high correlation of .865 between serum cholesterol and plasma lipid.

Spears and Balcomb (1966) studied the effect of dietary energy and protein on serum lipids in three genetic strains of White Leghorns. Mature body weights of the respective strains were A = 1.72 kg, B = 2.59 kg, and C = 1.22 kg. They found significant strain differences in
total serum lipids with strain C having highest levels and strain B lowest. They found that dietary treatments did not produce any significant effect on total serum lipids.

FOLLICULAR DEVELOPMENT:

The life span of the follicle is not known with certainty; follicles appear early in embryogenesis, but it is not known whether all of these give rise to the ova in the adult. Whatever the case, the post-embryonic development of the oocyte can be divided into three phases according to Marza and Marza (1935):

Phase 1: A period of slow growth by the deposition of yolk consisting mainly of neutral fat lasting for months or even years.

Phase 2: Intermediate phase of development (oocyte size from about 2 to 6 mm diameter) when some yolk protein is added, lasting for about 60 days. The yolk at this stage is usually referred to as "white yolk".

Phase 3: The phase of rapid growth of an ovum is variable between birds but usually within birds it remains fairly constant within a day. During this time the main mass of yolk is added and the oocyte increases in weight from about 0.5 gm to 20 gm usually within 7 to 11 days, though its duration may be as little as 5 days or as much as 14 days according to various investigators (Gilbert, 1971). Gilbert (1971) summarized the data from various investigators regarding the stages in the maturation of the oocyte. The summary shows that mean yolk weight in stage 2 ranges from .006 to .04 gm, with a mean
diameter of 2 to 4 mm and a mean yolk volume of .03 ml. The smallest follicle of stage 3 had a mean yolk weight of .15 gm with a mean diameter ranging from 8 mm and up.

According to Warren and Conrad (1939) the accumulation of yolk is regular and the increase in follicular size is almost linear with time during the third phase. At the same time there is a general decrease in the rate of yolk deposition maximum at 2.5 gm stage after which both the material transfer and permeability rates decrease more or less linearly with increasing size (Smith, 1959).

FOLLICULAR MATURATION AND ITS RELATION TO ECONOMIC TRAITS:

Lorenz et al. (1958) studied the interrelationship of the ovarian activity measured by the number of actively-growing follicles at autopsy and total number of eggs laid per 100 days from the onset of maturity and the liver lipids. They did not find any correlation between number of actively-growing follicles at autopsy and rate of production and liver lipids.

Jeep and Clancy (1968) demonstrated that broiler pullets laying at a rate of 56% had more (6.5 versus 5.6) follicles in rapid growth stages (5.6 gm) than White Leghorns laying at an 84% rate.

Jeep and Mohammadian (1969) in a study involving broiler strain (AG), normal (D), and dwarf (d) White Leghorn chickens found that the total weight of all follicles undergoing rapid yolk deposition in AG - broiler and in D normal was greater than their d Dwarf sisters. Part of this difference was due to fewer follicles undergoing rapid develop-
ment in the smaller birds like the dwarf birds. They concluded that the \textit{dw} gene reduces the rate of yolk deposition in the ovary, but that it does not reduce the rate of egg production in pullets weighing 2.6 kg at 36 weeks of age.

Udale \textit{et al.} (1972) found a significantly higher number (10.2 versus 5.0) of rapidly developing follicles (2.3 cm) in the line selected for high juvenile body weight (950 gm) than the one selected for low body weight (650 gm) in meat-type chickens. In a study with egg and meat type of turkeys, Nester \textit{et al.} (1970) found females of meat strain having more ova in rapid development (11.40 versus 9.65) and a larger total weight of ova in rapid development (137.6 versus 105.4 gm) than the egg strain. They found a non-significant correlation of \textit{-0.242} between number of ova in rapid development and egg production.

Beacon and Koemtz (1971) found a correlation of \textit{-0.089} between ovum weight and period of rapid development in Coturnix quail indicating that the ovum development and final ovum weight appear to be independently controlled in contrast to these two being related in turkeys (Nester \textit{et al.} 1970). They further found a negative correlation of \textit{-0.104} between the period of rapid development and total eggs laid during a four-week period indicating a negative relationship between rate of ovum growth and duration of the period of rapid development.
Gilbert (1971 b) found that the size of the group of rapidly growing follicles as well as the size of the pool of stage two follicles related to the sequence length. He further indicated the possibility that a control mechanism for sequence length might be operating as early as the transition from Stage 1 to Stage 2 rather than from Stage 2 to Stage 3.
MATERIALS AND METHODS

EXPERIMENTAL POPULATIONS:

In order to study the influence of body weight on various traits three types of dwarf birds with diverse mature body weights were used in the study. The three types of dwarf birds were D3, D5, and D6. Their proximate body weights and ancestry are given in the table below:

Table 2

Proximate Body Weights, Egg Weights and Ancestry of D3, D5 and D6 Birds

<table>
<thead>
<tr>
<th>Population</th>
<th>Female mature body weight</th>
<th>Mature body weight</th>
<th>Ancestry</th>
<th>dw locus</th>
</tr>
</thead>
<tbody>
<tr>
<td>D3</td>
<td>1.3</td>
<td>95.0</td>
<td>15/16 Leghorn</td>
<td>dw</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1/16 Sebright Bantam</td>
<td></td>
</tr>
<tr>
<td>D5</td>
<td>0.7</td>
<td>45.0</td>
<td>3/4 Leghorn</td>
<td>dw</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1/4 Sebright Bantam</td>
<td></td>
</tr>
<tr>
<td>D6</td>
<td>1.8</td>
<td>60.0</td>
<td>15/16 Leghorn</td>
<td>dwB</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1/16 Sebright Bantam</td>
<td></td>
</tr>
</tbody>
</table>

NOTE: D6 has no dwarfing (dw) gene but dwB from Sebright Bantam which is also a sex-linked recessive gene.

D5 are the dwarf 15/16 Leghorns with a dw locus.

D6 has not only dwarfing (dw) gene but also autosomal genes for small body size.
SIZE OF THE POPULATION:

Number of birds used in the experiment and their ages are given in the table below:

<table>
<thead>
<tr>
<th>Population</th>
<th>Number</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>D5</td>
<td>56 (45)*</td>
<td>48-56 weeks</td>
</tr>
<tr>
<td>D5</td>
<td>45 (54)</td>
<td>44-52</td>
</tr>
<tr>
<td>D6</td>
<td>50 (39)</td>
<td>48-56</td>
</tr>
</tbody>
</table>

*Figures in parentheses indicate the number of birds used to estimate plasma lipids.

EXPERIMENTAL PROCEDURE:

All of the birds used were maintained under 14 hours of day light with uniform feeding and management. For analysis a random sample of 10 to 12 birds were chosen from each of the D5 and D6 populations at a time. Birds from D5 population were analyzed about 2 to 3 months later when they were between 44 and 52 weeks old. Eggs were collected daily from each bird for 10 days. They were weighed individually on the day they were collected, hard boiled and yolks were separated and weighed. On the 10th day the birds were weighed and their shank length measured. Before the birds were killed, approximately 5 to 5 ml of blood was drawn into a heparinized test tube by direct heart puncture with the help of a syringe using heparin as the anticoagulant. Later
the blood was centrifuged, plasma separated into small glass vials, properly identified and stored in a freezer until they were analyzed for total lipids.

All of the birds were killed between 3:00 and 4:00 p.m. by dislocating their cervical vertebrae. The birds were stored in a cold room until they were dissected. All of the birds were dissected within three days after they were killed. The birds were cut open from the ventral side taking care not to damage any organs in the body cavity or follicles in the ovary. Livers were carefully dissected out, gall bladders removed and weighed on a Mettler's balance. After weighing they were put in a plastic bag with proper identification and stored in a freezer until they were analyzed for total lipids. All of the ova (follicles) weighing 300 mg and more were weighed on a Mettler's balance and their weights recorded. All of those ova weighing between 40-300 mg were weighed on a special microsensitive balance. Ova weighing below 40 mg were not weighed. However, their numbers were counted until they weighed as small as about 4 mg.

Many investigators have reported that ova start their rapid development when they reach a size of 6 mm or at the equivalent weight of .15 gm, as summarized by Gilbert (1971). Udai et al. (1972) considered .5 gm and more as the follicles in rapid development in a meat strain of chicken. However, they did not give any experimental evidence for considering .5 gm and more as rapid-developing follicles.

Hence, in order to determine the stage at which the follicles start developing rapidly in the three populations, the mean weight of
Figure 1.
Follicular Maturation in the birds of the three populations.
all ova were calculated for all the birds within a population by ranking those ova from heaviest weighing ones to least weighing ones. These means were plotted on a graph for all three populations as shown in Figure 1. From this figure it is evident that ova start their rapid development when they weigh around 200 mgm in all three populations considered here. Their weight of 200 mgm is closer to Gilbert's (1971) reported minimum size of 150 mgm than Udala et al. (1972) reported size of 300 mgm.

Therefore, all the ova weighing 200 mgm and more were considered as ova in rapid development (Phase III). And those ova weighing between 40 and 200 mgm as Phase II follicles, and those below 40 mgm as Phase I follicles arbitrarily.

Egg numbers were estimated from the number of eggs laid during the ten-day period plus any shelled egg in the oviduct during autopsy.

The average rate of daily yolk production was estimated by adding the yolk weight of each bird for the ten-day period plus any yolk in the oviduct and dividing this whole weight by 11. The figure eleven was arrived at by taking into consideration the ten-day period during which time eggs were collected and any yolks in the oviduct at autopsy as the 11th day.

ESTIMATION OF LIVER LIPIDS:

Liver lipid was estimated according to the method described by Folch et al. (1957). Frozen livers were thawed and weighed. Ten to fifteen gm of the liver was cut into small pieces and dried in a vacuum oven at a pressure of 25-27 lb/sq inch and 37.5°C temperature
for 10-12 hours. They were reweighed and the dry matter was calculated. These dried livers were ground individually in a mortar and pestle.

Out of this 2.0 gm of ground liver was taken in a thimble and extracted by chloroform methanol (2:1 v/v) mixture for 12 hours. Later the thimbles were dried in the oven for one hour and placed in a desiccator for two hours. They were reweighed and the difference was expressed on the basis of percent dry liver weight.

**ESTIMATION OF PLASMA LIPIDS:**

Total plasma lipids were estimated according to the method described by Heald and Hedman (1963).

The 0.5 to 1 ml of plasma was mixed with 9.5 ml of chloroform methanol (2:1 v/v) in a small conical flask and the mixture was filtered into a small beaker. The residue was washed with a small volume of chloroform methanol and filtered again into the beaker. This entire volume was then transferred into a separatory funnel. To this 2 to 3 ml of distilled water was added and shaken vigorously. This mixture was allowed to stand for 3-5 minutes by which time the aqueous phase gets separated from the chloroform methanol. This aqueous phase was removed and discarded. The chloroform methanol phase was then evaporated to dryness in a weighed aluminum pan. The pan was weighed again and the difference was calculated and expressed as gm/100 ml of plasma.

**STATISTICAL ANALYSIS:**

The data were statistically analyzed according to Snedecor (1967). To test the significance of population differences a mean separation
procedure was done according to the method of Duncan's new multiple range test modified by Kramer (1956) for unequal subclass numbers.
RESULTS AND DISCUSSION

The mean values with their standard errors of various characters studied for the three populations are summarized in Table 4.

BODY WEIGHT.

The mean body weights of the females killed between 44 and 56 weeks of age (Table 4) were 1735.37 gm, 1009 ± 95 gm and 693 ± 19 gm for D6, D5 and D3 populations, respectively. The means were significantly different (P < .01). Birds of the D3 population weighed about 50% of the weight of D6 birds. This is less than the findings of Tellico (1972) who found a body weight reduction of 35% in D3 birds due to the effect of \( d_w \) gene compared to D6 birds at 50 weeks of age. Such a high reduction in our D3 birds is mainly due to the low body weights of D3 birds, which weighed about 500 gm less than expected from this population. In an experiment conducted at Iowa State University it was found that \( d_w \) gene reduced body weight by 36.8%. French (1970) reported a reduction of 29.7% to 45.0% due to the effect of \( d_w \) gene. Castodio (1973) indicated that reduction of body weight due to \( d_w \) was about 10% compared to normal (\( d_w^+ \)).

Birds of D5 population weighed about 30% less than the birds of D3 population. This is mainly due to the presence of autosomal genes for small body size apart from the presence of \( d_w \) gene also in D5 birds.
<table>
<thead>
<tr>
<th>Character</th>
<th>Mean</th>
<th>S.E.</th>
<th>Mean</th>
<th>S.E.</th>
<th>Mean</th>
<th>S.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body Weight (gm)</td>
<td>1733</td>
<td>37</td>
<td>1009</td>
<td>25</td>
<td>693</td>
<td>19</td>
</tr>
<tr>
<td>Shank Length (mm)</td>
<td>93.0</td>
<td>0.6</td>
<td>72.0</td>
<td>0.6</td>
<td>59.0</td>
<td>0.6</td>
</tr>
<tr>
<td>Egg Weight (gm)</td>
<td>55.2</td>
<td>0.6</td>
<td>52.2</td>
<td>0.7</td>
<td>42.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Yolk Weight (gm)</td>
<td>17.2</td>
<td>0.2</td>
<td>15.1</td>
<td>0.3</td>
<td>13.5</td>
<td>0.2</td>
</tr>
<tr>
<td>Egg Number (11 days)</td>
<td>8.2</td>
<td>0.2</td>
<td>7.2</td>
<td>0.2</td>
<td>4.5</td>
<td>0.2</td>
</tr>
<tr>
<td>Liver Weight (gm)</td>
<td>26.7</td>
<td>1.5</td>
<td>36.4</td>
<td>1.5</td>
<td>21.1</td>
<td>1.3</td>
</tr>
<tr>
<td>Dry matter (%)§</td>
<td>42.5</td>
<td></td>
<td>41.0</td>
<td></td>
<td>35.6</td>
<td></td>
</tr>
<tr>
<td>Liver lipid (% dry wt)</td>
<td>28.3</td>
<td>1.9</td>
<td>43.4</td>
<td>1.9</td>
<td>36.6</td>
<td>1.8</td>
</tr>
<tr>
<td>Liver lipid (% wet wt)</td>
<td>22.6</td>
<td>1.2</td>
<td>20.5</td>
<td>1.1</td>
<td>13.6</td>
<td>0.8</td>
</tr>
<tr>
<td>Plasma Lipid (gm per 100 ml plasma)</td>
<td>1.94</td>
<td>0.16</td>
<td>1.72</td>
<td>0.14</td>
<td>2.21</td>
<td>0.19</td>
</tr>
<tr>
<td>Date of Yolk Production per day (gm)</td>
<td>12.6</td>
<td>0.3</td>
<td>9.5</td>
<td>0.3</td>
<td>5.3</td>
<td>0.2</td>
</tr>
<tr>
<td>Phase III Number of Follicles</td>
<td>6.8</td>
<td>0.24</td>
<td>5.5</td>
<td>0.24</td>
<td>3.5</td>
<td>0.24</td>
</tr>
<tr>
<td>Phase III Foll. Av. wt (gm)</td>
<td>5.7</td>
<td>0.18</td>
<td>6.6</td>
<td>0.23</td>
<td>4.1</td>
<td>0.29</td>
</tr>
<tr>
<td>Phase II No. follicles</td>
<td>12.9</td>
<td>0.75</td>
<td>10.0</td>
<td>0.58</td>
<td>6.6</td>
<td>0.57</td>
</tr>
<tr>
<td>Phase II Foll. Av. wt (mg)</td>
<td>92.89</td>
<td>2.32</td>
<td>99.58</td>
<td>2.04</td>
<td>98.53</td>
<td>4.56</td>
</tr>
<tr>
<td>Phase I No. of foll.</td>
<td>18.1</td>
<td>1.08</td>
<td>12.2</td>
<td>0.55</td>
<td>6.5</td>
<td>0.61</td>
</tr>
</tbody>
</table>

* Any two or three means not underscored by same line are significantly different (P<.01) and any two or three means underscored by the same line are not significantly different.

§ Significance not tested.
The three sites of females (1.7, 1.0, and 0.7 kg) used for comparisons here were below the normal weight (2.0 kg) of commercial Leghorns.

SHANK LENGTH:

The mean shank lengths were 93 ± 0.6 mm, 72 ± 0.6 mm, and 59 ± 0.6 mm for the birds of D6, D3, and D5 populations, respectively (Table 4). The means were significantly different from each other (P<0.01). The reduction of shank length due to Dv gene reported in the literature ranges from 21% to 29.5% (Table 1). The reduction of shank length due to DvB was estimated to be 3.5% (Custodio, 1973).

Using shank length as a measure of body size D3 and D5 can be compared directly since they are both Dv. D6 would be expected to have proportionately longer shanks at the same body weight because DvB does not disproportionately reduce shank length (Custodio, 1973).

BODY WEIGHT AND SHANK LENGTH:

Shank length within a population estimates body size if genes affecting shank length variation are general, affecting growth of all parts of the body.

The regression of body weight (gm) on shank length (mm) and the correlations between them in the three populations are given in Table 5. Both the correlations and the regression coefficients were highly significant (P<0.01).

From the table it is evident that there is a high correlation between shank length and body weight. The regression of body weight
Table 5

Relationship Between Body Weight and Shank Length

<table>
<thead>
<tr>
<th>Population</th>
<th>Correlation Coefficient</th>
<th>Regression of body weight (gm) on shank length (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D6</td>
<td>.63**</td>
<td>39.1**</td>
</tr>
<tr>
<td>D5</td>
<td>.75**</td>
<td>32.8**</td>
</tr>
<tr>
<td>D5</td>
<td>.53**</td>
<td>16.1**</td>
</tr>
</tbody>
</table>

** Statistically Significant (P<.01).

on shank length was 39.1 gm and 32.8 gm increase in body weight per mm increase in shank length for the birds of D6 and D5 populations. The correlations and regressions for D6 and D5 birds agree with the findings of Telloni (1972), who in a study involving D6 and D5 populations found significant correlations of .64 and .62 between shank length and body weight. The regressions of body weight on shank length he found were 40.8 gm and 31.8 gm per mm increase in shank length for the birds of D6 and D5 populations, respectively.

The correlation of .53 and a regression coefficient of 16.10 gm for the birds of D5 population is slightly lower than the findings of Akinkuolle (1974) who in a similar population found a correlation of .68 between shank length and body weight and a regression coefficient of 22.4 gm per mm increase in shank length. However, the birds he used weighed 70 gm more than ours at the same shank length.
Thus, the regression of body weight on shank length was less by 7 gm to 23 gm per mm increase of shank length in the dwarf (dv) birds of D5 and D3 populations compared to the non-dwarf (dv<sup>2</sup>) birds of D6 population. Therefore, the dv gene appears to reduce the amount of change in body weight per unit change of shank length.

The correlations between shank length and body weight reported in the literature have also been high. Lerner (1946) found a high correlation of .79 between shank length and 36-week body weight in a line of White Leghorns selected for shank length. Morris et al. (1966) reported a correlation of .70 between shank length and skeleton weight and suggested that shank length should give a good estimate of body size.

**Yolk weight:**

The mean yolk weights were 17.2 ± 0.2 gm, 15.1 ± 0.3 gm and 13.5 ± 0.2 gm for D6, D5, and D3 populations, respectively (Table 4). Means were significantly different from each other (P< .01). A 3-gm reduction in weight would be expected to be equivalent to only 0.6 gm in yolk weight (Morion et al., 1964). Therefore, D5 had relatively smaller yolk in proportion to its egg size. The D5 yolk weight was expected to be 1.92 gm smaller than that for the D3 pullets, and about 0.5 gm smaller than those of D6. Therefore, the relation of yolk weight to egg weight in D5 was closer to that of D6 than D3. Morion et al. (1964) found yolk weight of 53.3 gm egg size to be 16.4 gm. Apparently, D5 eggs had less yolk than would be expected on the basis of their egg size. Whether this is a peculiarity of the D5 population or a biased sample of females, remains to be tested. However, the
regressions for egg weight on yolk weight were very similar within each strain. Therefore, on the basis of the present data, it is probable that birds of D3 population may deposit more albumen and/or shell in proportion to the yolk size.

**EGG WEIGHT:**

The mean egg weights were 55.2 ± 0.6 gm, 52.2 ± 0.7 gm and 48.6 ± 0.6 gm for D6, D3, and D5 populations, respectively (Table 4). Means were significantly different from each other (P<.01). Comparing the egg weights in relation to the body weights, birds of D6 population laid eggs weighing 3.8% of their body weight, birds of D3 population about 5.2% and birds of D5 population about 6.2% of their body weights. Similar results were found by Telloni (1972) in D6 and D3 birds and by Akinkucile (1974) in D5 birds. Hutt (1959) who compared the egg weights of normal and dwarf birds obtained similar results. He concluded that smaller birds tend to lay larger eggs that are larger in relation to body size, whether the birds carry dw gene or not. Therefore, the D3 eggs being only 3 gm below those from D6 were much larger than expected for such a small female. Conversely, D5 eggs were relatively smaller but close to that of the previous generation of this population.

**EGG WEIGHT AND YOLK WEIGHT:**

The phenotypic correlations between egg weight and yolk weight for the three populations were all high and significant (P<.01). They were .79, .83 and .72 for D6, D3, and D5 populations, respectively.
The corresponding regression coefficients of egg weight on yolk weight were 1.78 gm, 1.80 gm, and 1.85 gm.

The above correlations and regressions indicate a close relationship between egg weight and yolk weight. The correlations agree with the report of Jull (1924), who reported a correlation of .82 between egg weight and yolk weight. There are other reports which are lower than ours, .558 (Ammons, 1951), .593 (Jaffe, 1964) and .64 (Singh et al., 1972). The similar regression coefficients for the three populations indicate that irrespective of the body weight differences, a given yolk weight influences egg size equally in all three populations. Wenzl (1972) did not find any differences in the proportion of yolk and albumen to the total egg in dwarf and normal chickens. He concluded that _sv_ gene does not modify the proportion of yolk and albumen.

### Table 6

<table>
<thead>
<tr>
<th>Population</th>
<th>Correlation coefficient</th>
<th>Regression of egg weight (gm) on yolk weight (gm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D6</td>
<td>.79**</td>
<td>1.70**</td>
</tr>
<tr>
<td>D3</td>
<td>.83**</td>
<td>1.80**</td>
</tr>
<tr>
<td>D5</td>
<td>.72**</td>
<td>1.88**</td>
</tr>
</tbody>
</table>

**Statistically Significant (P < .01).**
Body weight which influences egg size may also influence yolk size. The phenotypic correlations between body weight and yolk weight were .44, .51, and .31 for the birds of D6, D5, and D5 populations, respectively (Table 7). All of the correlations were statistically significant indicating that there is a close association between body weight and yolk weight. The corresponding regressions of yolk weight on body weight were .003 gm, .007 gm, and .004 gm per gm increase in body weight in D6, D5, and D5 populations. It is evident that the influence of body size on yolk size is greater in D5 birds than in D6 of D5 birds. However, D5 birds had proportionately less yolk in their eggs compared to the eggs of D6 and D5 birds.

Table 7
Relationship Between Body Weight and Egg Weight and Between Body Weight and Yolk Weight

<table>
<thead>
<tr>
<th>Relationship</th>
<th>D6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body weight X yolk weight, Correlation coefficient</td>
<td>.44**</td>
</tr>
<tr>
<td>Regression of yolk weight (gm) on body weight (gm)</td>
<td>.003**</td>
</tr>
<tr>
<td>Body weight X egg weight correlation coefficient</td>
<td>.47**</td>
</tr>
<tr>
<td>Regression of egg weight (gm) on body weight (gm)</td>
<td>.007**</td>
</tr>
</tbody>
</table>

** Statistically Significant (P < .01)
* Statistically Significant (P < .05)
BODY WEIGHT AND EGG WEIGHT:

The phenotypic correlations between body weight and egg weight were .47, .59, and .54 for B6, B3, and B5 populations, respectively (Table 7). All the correlations were highly significant (P < .01).

The correlations obtained here are higher than the summarized reports of Kinney (1969), who reported a correlation of .34 between pullet body weight and pullet egg weight and a correlation of .36 between mature body weight and mature egg weight.

This could indicate that body weight and egg weight are more closely related in dwarf chickens than in their normal sisters. For Merat (1969) observed a similar relationship and concluded that body weight and egg weight are more closely related in dwarf small-bodied pullets than in their normal sisters. However, Butt (1959) who studied this relationship in dwarf and normal bodied birds concluded that smaller birds tend to lay eggs that are larger in relation to body size whether they carry Dw gene or not.

The correlations agree with similar findings of Telfoni (1972), who found correlations of .47 and .56 between body weight and egg weight for the birds of B6 and B3 populations at 50 weeks of age. Akinkuolie (1974) found a correlation of .59 between body weight and egg weight in a population of B5 birds having a 52-week mean body weight of 760 gm.

The regressions of egg weight on body weight were .007 gm, .016 gm and .016 gm for the birds of B6, B3, and B5 populations, respectively (Table 7). All the regressions were highly significant (P < .01).
The regressions for D5 and D5 populations indicate that the influence of body weight on egg weight is similar in the two \( d_w \) populations. Whereas, the same relationship for D6 population indicates a less influence of body weight on egg weight. Marble (1931) indicated that bigger birds do not lay proportionately bigger eggs. Therefore, from the present data available egg weight seems to be more influenced by body weight in small-bodied birds.

**EGG PRODUCTION:**

The average number of eggs laid during the 10-day period were 8.2 ± 0.2, 7.0 ± 0.2, and 4.5 ± 0.2 for D6, D5, and D5 populations (Table 4). The means were significantly different from each other (\( p < 0.01 \)).

This indicates that rate of lay was lower in D5 birds than that of D6 and D5. However, there was only one egg difference in the number of eggs laid during the 10-day period by the birds of D6 and D5 populations. It is known that \( d_w \) gene reduces rate of lay by 4 to 19% (Table 1). The reduction here is 11%, which is within the reported range. The D5 and D6, or D5, birds are not comparable directly. Therefore, part of the 45% reduction in rate of lay in D5 from that of D6 may be due to genes other than those affecting body size.

**RATE OF YOLK PRODUCTION:**

In order to find the quantity of yolk a bird produces per day, the yolk weights in the eggs for 11 days were summed and divided by the number (11) of days. The average quantity of yolk produced per day
calculated on this basis for the birds of D6, D3, and D5 populations were 12.6 ± 0.3 gm, 9.4 ± 0.3 gm, and 5.3 ± 0.3 gm, respectively (Table 4).

**BODY WEIGHT AND EGG NUMBER:**

The phenotypic correlations between body weight and egg number were -.17, .43, and .31 for D6, D3, and D5 populations, respectively (Table 8). The correlations for D3 population (P < .01) and D5 population (P < .05) were significant, indicating the influence of body weight on egg number in these birds.

Telloni (1972) found a correlation of -.16 and .05 between body weight and egg number for D6 and D5 populations. Atinkuolile (1974) obtained a correlation of .62 between body weight and egg production in a D5 population which was highly significant.

The correlations obtained here for D3 and D5 populations are higher than those reported in the literature. Kinney (1969) summarized the phenotypic correlations between body weight and short term production as .01. Therefore, it appears that increase in body size may favor higher egg production in these very small females.

**EGG WEIGHT AND EGG NUMBER:**

The phenotypic correlations between egg weight and egg number for the three populations ranged from -.07 for D6 population to .19 in D5 population. All of the correlations were nonsignificant (Table 8). Atinkuolile (1974) obtained nonsignificant correlation of .18 between egg weight and egg number in the birds of a D5 population. Herst (1969)
obtained a nonsignificant correlation of .28 between egg weight and egg number in a dwarf chicken population. The reports in the literature regarding the relationship between egg weight and egg number have been very low, .08 as summarized by Kinney (1969). Therefore it appears that there is no relationship between egg weight and egg number in these birds.

Table 8
Correlations Between Body Weight and Egg Number and Between Egg Weight and Egg Number

<table>
<thead>
<tr>
<th>Correlation</th>
<th>D6</th>
<th>D3</th>
<th>D5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body weight x egg number</td>
<td>-.17</td>
<td>.43**</td>
<td>.51*</td>
</tr>
<tr>
<td>Egg weight x egg number</td>
<td>-.07</td>
<td>.18</td>
<td>.19</td>
</tr>
</tbody>
</table>

** Statistically significant (P < .01)
* Statistically significant (P < .05)

LIVER WEIGHT:

The mean liver weights were 52.7 ± 1.5 gm, 36.4 ± 1.5 gm, and 21.1 ± 1.3 gm for D6, D3, and D5 populations, respectively (Table 4). Comparing the liver weights in relation to their body weights, liver weight formed about 3.0%, 3.6%, and 3.0% of the body weights of the birds of D6, D3, and D5 populations, respectively. It can be observed that liver weight in birds of D3 population was heavier in proportion to their body weights compared to the birds of D6 and D5 populations at the same age. It is not known whether or not the w gene has any
influence on organ weight in relation to body weight. However, this range of liver weight falls within the range of 2 to 4% of the body weight reported by Hafez (1955), Al-Debagh and Abdulla (1965) and Boldizar and Kosman (1968).

LIVER LIPID:

The average quantity of liver lipid estimated on percent dry liver weight basis was 92.3 ± 1.9%, 98.4 ± 1.9% and 36.6 ± 1.8% for the birds of D6, D5, and D5 populations, respectively. The corresponding values for lipid on percent wet liver weight basis were 22.6 ± 1.2%, 20.5 ± 1.1% and 15.6 ± 0.8% (Table 4). Means were not significantly different between D6 and D5 populations.

These values appear to be higher than the values reported by Nockels (1973), Wills et al. (1972), and Thayer et al. (1973), who reported values ranging from 10 to 35% on percent dry weight basis in laying birds from 22 to 50 weeks of age. However, there are other reports which have reported liver lipid values of 43.8 ± 4.1%, Lavielle and Bray (1970), 48.5% Wolford and Polin (1971), and 25.8% to 49% by Gerlich et al. (1974) without any signs of liver hemorrhage or any signs of fatty liver syndrome.

Schmahl and Griffith (1973) fed a basal diet to a control group of commercial White Leghorn birds. They found liver lipid on dry weight basis as high as 53.8% to 56.6% at 20 weeks of age and 58.8% at 64 weeks of age.

The values obtained here for the three populations indicate a trend. It can be seen that as the dry matter content of liver increases the
lipid content of liver also increases. The corresponding dry matter (\(\%\)) were 42.6\%, 41.0\%, and 35.6\% for the liver of D6, D3, and D5 populations, respectively (Table 4).

The total content of lipid in the liver calculated on this basis was 12.0 gm, 10.0 gm, and 5.0 gm for the birds of D6, D3, and D5 populations, respectively. Comparing their content of lipid to the total wet liver weight of each population, D6 had about 22.6\%, D3 about 27.3\% and D5 had about 23.7\% of its liver weight. This shows that smaller birds tend to have more lipid in proportion to their liver weights, than larger birds.

**BODY WEIGHT AND LIVER WEIGHT:**

The phenotypic correlations between body weight and liver weight were .55, .38, and .57 for D6, D3, and D5 populations, respectively (Table 9). The corresponding regressions of liver weight on body weight were .0237 gm, .0224 gm, and .0587 gm. All of the correlations and regression coefficients were highly significant (P < .01).

Dashir and Pellet (1967) measured body and liver weights in three different breeds and 2 breed crosses, over an age range of 0-8 weeks. They found correlations ranging from .81 to .96 for all ages in these young birds. The regression coefficients ranged from .0219 to .0318 and were significant. They concluded by stating that organs like liver, spleen, and heart would be expected to increase in weight at the same rate as total weight more than others because of their functional relationship to growth. The correlations reported here were lower than the reports of Dashir and Pellet (1967), the main reason being that the
<table>
<thead>
<tr>
<th>Relationship</th>
<th>D6</th>
<th>D3</th>
<th>D5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body weight X liver weight correlation coefficient</td>
<td>.50**</td>
<td>.50**</td>
<td>.57**</td>
</tr>
<tr>
<td>Regression of liver weight (gm) on body weight (gm)</td>
<td>.0237**</td>
<td>.0225**</td>
<td>.0387**</td>
</tr>
<tr>
<td>Body weight X liver lipid correlation coefficient</td>
<td>.13</td>
<td>.02</td>
<td>.50**</td>
</tr>
<tr>
<td>Regression of liver lipid (% dry weight) on body weight (gm)</td>
<td>.007</td>
<td>.001</td>
<td>.048**</td>
</tr>
<tr>
<td>Liver weight X liver lipid correlation coefficient</td>
<td>.47**</td>
<td>.57**</td>
<td>.63**</td>
</tr>
<tr>
<td>Regression of liver lipid on liver weight</td>
<td>.560**</td>
<td>.732**</td>
<td>.868**</td>
</tr>
</tbody>
</table>

** Statistically significant (24.01)
proportion of organ weight to body weight is not constant with age (Burger et al., 1960).

Frankham and Doornenbal (1970) found no significant differences in the weights of the livers in strains of White Leghorns at prepuberal age, two strains were selected for egg production. However, when the birds were 440 days old they found that strains selected for higher egg production had significantly larger livers compared to the parent group. The regression coefficient of liver weight on body weight was .0237 and significant (P<.01).

The regression coefficients obtained here for the three populations agree with the reports of Baghiri and Pellett (1967) and Frankham and Doornenbal (1970). Therefore, the correlations indicate that there is a definite influence of body weight on liver weight in all the birds of the three populations. However, the regression (.0387 gm) of liver weight on body weight in the birds of D5 population indicate that liver of D5 birds changes more per unit of body weight change than D3 and D6.

BODY WEIGHT AND LIVER LIPIDS:

The phenotypic correlations between body weight and liver lipid were .15, .02, and .50 for D6, D5, and D3 populations, respectively (Table 9). The corresponding regressions of lipid (%) on body weight (gm) were .001%, .001%, and .048%. The correlation and regression coefficients were significant only for D5 population (P<.01). This further seems to confirm our earlier observation that body weight which influences liver weight more in D5 birds than in D6 or D3 birds, also influences liver lipid production in D5 birds.
Gerlich et al., (1974) who studied liver lipid content in twenty varieties of 71-week-old laying hens managed in three confinement systems found a correlation of .140 between liver lipid and body weight in hens confined two per cage.

The high correlation observed here for D5 birds may indicate that this relationship may be necessary for the birds with lower body weights to produce more lipids, which in turn may influence the size of the egg. This relationship may be one of the possible explanations as to why a small hen lays a larger egg in proportion to its body size.

LIVER WEIGHT AND LIVER LIPIDS:

The phenotypic correlations between liver weight and liver lipid were .47, .57, and .62 for D6, D5, and D5 populations, respectively. The corresponding regressions of liver lipid (% dry weight) on liver weight (gm) were .560%, .732% and .888% (Table 9). All of the correlations and regressions were highly significant (P<.01).

These values show that there is a definite influence of liver size on its lipid content. Earlier Chaikoff et al. (1941) demonstrated that increase of liver lipids was shown by increase in liver weight as the bird approached maturity.

The regression of liver lipid on liver weight in these three populations shows a trend. It can be seen that as the size of the bird and size of the liver decrease the percent change of liver lipid per unit change of liver weight increases. Thus, birds of D5 population had highest percent change of liver lipid per unit change of liver weight.
PLASMA LIPID:

The average quantity of plasma lipid was 1.96 ± 0.16 gm, 1.72 ± 0.14 gm, and 2.23 ± 0.19 gm/100 ml plasma in the birds of the D4, D3, and D5 populations (Table 4). There were no significant differences between the means. Speers and Halloun (1966) who measured plasma lipids in three strains of White Leghorns with their mature body weights ranging from 1.22 to 2.59 kg observed significant strain differences in their level of plasma lipids. The strain with the lowest body weight had the highest level and the strain with the highest body weight had the lowest level of plasma lipid.

Medway and Yare (1959) showed that the plasma volume in the domestic fowl falls from about 8.7% of body weight at one week of age to 4.6% at maturity. Calculating on the basis of volume of plasma and the lipid content of plasma, it was found that birds of D5 population with a mature weight of 700 gm have 32.2 ml total blood plasma and 0.718 gm lipid. Similarly, birds of D3 population had 0.791 gm in 46.0 ml of plasma and birds of D6 population had 1.547 gm in 79.76 ml of plasma. This shows that the total content plasma lipid a bird has, is less in birds with lower body weights.

There were no significant differences in the level of plasma lipids among the three populations. However, it seems probable that birds with lower body size may have slightly higher levels of plasma lipid per unit of blood so that these birds can maintain a steady supply of lipid to the follicles for the production of larger eggs in proportion to their body weight.
CORRELATIONS:

The correlations between plasma lipid and body weight were small and nonsignificant. Similar correlations were observed between plasma lipid and liver weight. However, a significant correlation of .36 was observed between plasma lipid content and liver lipid content in the birds of D6 populations indicating the possibility that liver lipid may influence plasma lipid in the D6 birds.

FOLLICULAR MATURATION:

The number and average weight of follicles of various stages for the three populations are given in Table 4. From the table it is evident that birds of D6 population had significantly more follicles at Phases I, II and III than the birds of D5 and D5 populations. Further, the weight of Phase III follicles was significantly heavier in D6 birds than in D5 and D5 birds. However, there were no significant differences in the weights of Phase II follicles between the three populations. This shows that follicles before they start developing rapidly, lie dormant in the ovary.

A fewer number of follicles in Phases I, II, and III and lower weights of Phase III follicles in the two D5 populations compared to D6 population seem to confirm the reports of Josp and Mohammadian (1969) that dw gene reduces rate of yolk deposition in the ovary.

Body weight may also have an influence on the number of follicles. For Udale et al. (1972) found a significantly higher number (10.2 versus 5.0) of follicles (4.5 gm) in rapid development in a line selected for high juvenile body weight (850 gm), than in one selected for low body weight (600 gm) in meat type of chickens.
SUMMARY AND CONCLUSIONS

Females from strains B6, D3, and D5 weighing 1.7, 1.0, and 0.7 kg, respectively, at 44-56 weeks of age were used in this study. The B6 and D3 strains were almost equal in their autosomal inheritance. Birds of B6 had the Bentam (dwB) gene while D5 carried the (dw) gene. The D5 birds had autosomal genes for small body size apart from having dwarf (dw) gene also. A random sample of 10-12 birds were chosen at a time. Their eggs were collected for this period, weighed, hardened, yolks separated and weighed. Before the birds were killed on the tenth day, 3-5 ml of blood was collected for plasma lipid estimation. After killing, the livers were removed, weighed and analyzed for liver lipids. Follicles ranging from 40 mgm and up were weighed individually and their numbers recorded. Various results obtained are as follows:

1. The correlations between shank length and body weight within populations (strains) ranged from .53 to .75. The regressions of body weight on shank length was less by 7 gm to 25 gm per mm increase of shank length in the dwarf (dw) birds of D5 and D5 populations compared to the nondwarf (dwB) of B6 population.

2. The interrelationship between body weight, egg weight, and egg number showed that increase in body weight would favor egg production in D5 birds. The calculated partial correlation between body weight and egg number was .47 (P<.01) for D5 bird with egg weight as constant.
3. The correlations between egg weight and yolk weight ranged from .72 to .83 (P < .01). Eggs of D5 birds had relatively less yolk in proportion to their egg weight. However, the regressions of egg weight on yolk weight were similar within each strain indicating that birds of D5 may deposit more albumen and/or shell compared to D6 and D9 birds.

4. The correlations between body weight and liver weight ranging from .38 to .57 and between liver weight and liver lipid ranging from .46 to .63 were all high and significant (P < .01).

5. The regressions of liver weight on body weight of .0387 gm and liver lipid on liver weight of .891 were highest for D5 birds.

6. The liver lipid content on percent dry weight was significantly different (P < .01) between D5 and the other two strains. However, the difference was not significant between D5 and D6 strains. The values ranged from 36.6% in D5 birds to 52.3% for D6 birds.

7. The blood plasma of D5 birds seem to contain more lipid per unit of plasma than birds of D5 or D6. However, the mean levels were not significantly different from each other.

8. Birds of D6 population laid more eggs in the 11-day period than D3 or D5. Further, the birds of D6 population had significantly (P < .01) more number of follicles at rapid development (Phase III) and their average weights were higher than those of D3 or D5.

9. All the ova in the ovary of each female, .04 gm and more were weighed. By ranking them from heaviest to least weighing it was found that follicles start developing rapidly when they weigh around 200 mg.
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