

## FIFTEEN YEARS OF OBSERVATIONS ON THE DWARF GENE IN THE DOMESTIC FOWL (1)(2)

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### SUMMARY

Observations on dwarfism at the Oregon A. E. S. go back to 1952 but systematic study began in 1956. Dwarf mutants have been observed in *Cornish* and in two inbred *Leghorn* lines and were also obtained from a local hatcheryman.

A mosaic female for dwarfism and normal size was observed in the progeny of dwarf males mated to normal size females. This female is genetically dwarf since all progeny has been dwarf. A spur has developed on the larger shank. It is hypothesized that the polar body with the sex chromosome bearing the gene for normal size has reunited with one of the first two cleavage cells. This has resulted in a half-dwarf female and a half-normal-size triploid neuter. Cytological analysis of blood and feather follicles has revealed no karyotypic abnormality.

A sex-linked recessive lethal has been observed in a dwarf male with exceptionally high semen production. Half of the female embryos from carrier males die very early and are often misidentified as infertile. Dwarf-males mated to normal females would be a common method of obtaining dwarf-laying stock but the disparity in size could possibly reduce fertility level in natural matings.

Male to female ratios of 1 : 15 and 1 : 10 gave until this year approximately 80 per cent fertility. A period as long as three or four weeks appeared necessary to reach that level of fertility although it continued to increase but slowly for 30-35 days. In the period 1966-1971 males were moved directly from dark to lighted pens with the females. This year the males were first exposed to fifteen hours of light for a month before being placed with the females. Fertility has climbed much faster, reaching 90 per cent in 15 days, 95 per cent in 21 days but the ratio was still IM : 10FF.

Pure-line dwarfs kept in individual cages and reproduced by artificial insemination exhibited fertility and hatchability comparable to those obtained with normal size females.

In our genetic selection for hen-housed egg production on the basis of individual and family performance results were for a time disappointing. This apparently occurred because polygenes for hypothyroidism were segregating as a result of the inbreeding that accompanied our selection. Age at first egg increased to 32.5 weeks but it has gradually decreased to 24.3 weeks in the current generation, which is still 1.7 weeks later than in our *OSU* Production Line.

Hen-housed egg production was also disappointing in a number of years but it began to show improvement in the last three generations. It is now 83.4 per cent as high as that observed in the Production Line at 40 weeks of age. Egg size has gradually increased. Body weight has not changed

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because of the restriction placed on it in our selection. It would very likely have changed as a correlated response to our selection for egg size.

Nutrition studies have been conducted with populations ranging from 240 birds in early years to over 1,200 dwarf layers in more recent years in groups of 60 to a pen. We have determined that dwarf pullets, even after allowing for their delayed sexual maturity, require less feed to reach laying age. The nutrition studies have involved the influence of (1) calcium levels ; (2) double the normal level of vitamin-trace mineral supplement ; (3) protein levels up to 21 per cent ; and (4) supplementation with methionine, lysine and linoleic acid.

Although egg production plateaued at the 15 per cent protein level, egg size continued to increase up to 21 per cent. The addition of .05 per cent methionine was found to increase egg production and egg weight significantly and to levels comparable to those observed with a 21 per cent protein diet. Currently a low level of Protamone is being fed to layers reared with and without a Protamone supplement, but the level had to be cut in half to .0167 per cent as it depressed egg production.

Physiological studies have involved observation of the hypophyses, thyroid, adrenals and ovaries of both growing and mature dwarf females, and also a bioassay of hypophyseal homogenates in immature hypophysectomized rats. Although the thyroids of dwarf females were found to be smaller than those of normal birds at 7-13 months of age it could not be ascertained from the bioassay that alterations in the pituitary thyrotropic activity are responsible for the thyroid disturbances in the dwarfs.

The pituitary bioassay results do not support the contention of accumulation of somatropic hormone in the pituitaries of dwarf birds. Observations on ACTH and on gonadotropin potency of the dwarf pituitaries were also made.

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Observations on dwarfism at the Oregon Agricultural Experiment Station go back to 1952 when one of us (PEB) obtained a dwarf male ( $\neq$  4,001) in the progeny of a cross between a S. C. *White Leghorn* male and a *Cornish* hen. Dwarf female segregates have also been observed in our *Cornish* line. In 1956 a dwarf *Leghorn* female was observed in the progeny of a cross between our OSU Production Line and a male of another strain. The comparatively large egg laid by that hen (26 oz +) aroused our interest in the economic potential of dwarfism in layers. This interest had been first kindled by the studies of BIRD and SINCLAIR (1939) and of BYERLY (1941) which demonstrated the tremendous influence of body size on feed requirements for egg production. The brief report of KEARL (1957), in which he showed that labor efficiency and increased egg production per hen were the main reasons for increased efficiency in egg production, and that actually there had been little if any improvement in feed efficiency of egg production in the preceding twenty years, firmed up this interest in investigating the economic potential of dwarfism still further. It was reasoned that one would possibly expect diminishing returns in searching for additional eggs and increased labor efficiency but that reduced feed consumption was definitely a most profitable avenue to explore. Decreased body size is of course assurance of decreased feed consumption. This has been taken advantage of through the gradual monopoly of *Leghorns* on egg production as well as the decreasing body size of many strains of layers. One day while explaining these facts to a group of visiting poultrymen and showing them some of our midget chickens, one of them, Mr. Barry Brownell, mentioned that he had a few such small chickens himself and that he would gladly give them to our station. This gift increased the size of our population of miniature chickens and really launched us on what has become an increasing research commitment at the Oregon Agricultural Experiment Station. Serendipity thus led us to what we think is a promising avenue in the continuing

search for greater efficiency in egg production. The dwarf gene appears to have a relatively high mutation rate judging from our observations and the reports and correspondence received from various countries, the most recent being from Australia. It remains to be determined whether we are dealing in all these instances of sex-linked dwarfism with genes identical by descent or simply alike in state. HUTT (1959) predicted the dwarf gene should eventually be found in many breeds of Bantam fowl into which the mutant was probably incorporated over the years in light of its recurrence. We have continued to obtain a few dwarf segregates from an inbred line which, to our regret, because of limited facilities, we were forced to mix with our other dwarfs. We have subsequently hypothesized that some of these dwarf segregates were probably of the hypothyroid type described by COLE (1966). They have complicated our selection program. Today we would like to review some of our findings under the headings of genetics, reproduction, genetic selection, nutrition and physiology.

## GENETICS

In the first year of our more intensive studies, in 1957, we established that the dwarf trait we were working with was determined by a sex-linked recessive gene, possibly homologous to that described by HUTT (1949, 1953) in the *New Hampshire* breed. Correspondence with Dr HUTT indicated that he had yet another dwarf gene under study, this time in Single Comb *White Leghorns*. We have since determined that it was likely of the same origin as some of the birds donated to the Oregon Agricultural Experiment Station. HUTT (1959) in reporting his studies on dwarfism in

TABLE I

*Relative performance of sex-linked dwarf layers  
and their normal sisters*

Sixteen periods of 28 days. April 1959-May 1960, BERNIER and ARSCOTT (1960)

*Performances comparées de pondéuses portant le gène de nanisme lié au sexe  
et de leurs sœurs normales*

Seize périodes de 28 jours. Avril 1959-mai 1960, BERNIER et ARSCOTT (1960)

	Normal	Dwarf	$\frac{\text{Dwarf}}{\text{Normal}} \times 100$
Number Aver. ....	118.3	118.5	
Body weight (lbs) .....	4.46	2.87	64
Sexual maturity (weeks) ....	23.4	24.6	105
Feed consumed (lbs) .....	6.27	4.13	66
Eggs produced p. bd. ....	13.39	11.13	83
Egg weight (ozs./doz.) ....	25.5	22.8	89
Specific gravity (coded) ....	10	9.1	91
Livability % .....	83	95	114
Lbs. feed			
Ib. live weight .....	1.41	1.44	102
doz. eggs .....	5.62	4.45	79
doz. 24 oz. eggs .....	5.29	4.68	88

both the *New Hampshire* and the Single Comb *White Leghorn* expressed skepticism on the economic future of the dwarf layer because of its reduced egg production and egg size. However he recognized the possibility that its feed consumption might compensate for the lower egg production and egg size. When this study of HUTT was published we already had an experiment under way to compare the performance of 120 normal and 120 dwarf sister segregates from a mating of males heterozygous for dwarfism with normal females. We found, BERNIER (1960), and BERNIER and ARSCOTT (1960), Table 1, that dwarf hens did not lay as well as their normal size sisters and that their eggs were not as large but that their reduced feed consumption, when expressed on a per dozen of 24 oz. basis, made the dwarf layers not only competitive but superior.

These results encouraged us to continue our studies and to expand them by undertaking a genetic selection program as well as an investigation of the nutritive requirements of dwarf layers. We reasoned that the reduction in body size caused by dwarfism meant a reduction in maintenance requirements and therefore that a greater proportion of the feed intake would have to satisfy the requirements for egg production. In the first few years we had to combine our nutrition and selection studies because of limited facilities and numbers but as our enthusiasm grew we decided to undertake nutrition studies on a larger scale by substituting dwarf for normal size layers in our regular nutrition research program in the Poultry Department. It was also decided to produce the larger number of dwarf layers necessary for these nutrition studies by mating dwarf males to normal size females. This program has been continued since and in one year we were presented with a gift in the form of an unusual bird which we would like to introduce to you at this time.

#### MOSAIC FOR DWARFISM

A mosaic for dwarfism and normal size, this bird, we would like to remind you, is the progeny of a dwarf male and of a normal female. Phenotypically if it is a female it should be a dwarf but to our surprise we found it to be a half-sider, a mosaic or a case of lateral asymmetry as the illustrations clearly show (fig. 1 a-1 b).

The mosaic is without question normal on its right side but dwarf on its left side. It has not been an exceptionally good layer but it has laid well and when mated to a dwarf male it has given exclusively dwarf progeny, both male and female in a 1 : 1 ratio. The large spur on the right leg has developed this last year. There is a sizeable catalog of mosaics in the poultry genetics literature which was reviewed by HOLLANDER (1944). What are the possible explanations for our half and half mosaic?

The most generally accepted hypotheses for lateral asymmetry in the domestic fowl are those proposed by CREW and MUNRO (1938, 1939); a slight discrepancy in size, less than 4 p. 100, would be explained by the elimination of an autosome at the first cleavage division whereas a major discrepancy (10-15 p. 100) would be the result of non-disjunction at the same stage, an autosome being lost from one side and gained on the other.

We cannot accept CREW and MUNRO's hypothesis of non-disjunction of an autosome to explain our case. The sex chromosome carrying the gene for normal size needs to be reintroduced into the zygote at the first cleavage. Non-disjunction of

$Z^{aw}$  at the first cleavage would result in the absence of  $Z^{aw}$  on one side and it would probably be lethal whereas  $Z^{aw}Z^{aw}$  would probably not be a simple dwarf female.

So far we favor one hypothesis and Dr R. N. SHOFFNER, University of Minnesota (Personal communication) has offered another that is a possibility but a remote one in our estimation because of the two chance events it requires.

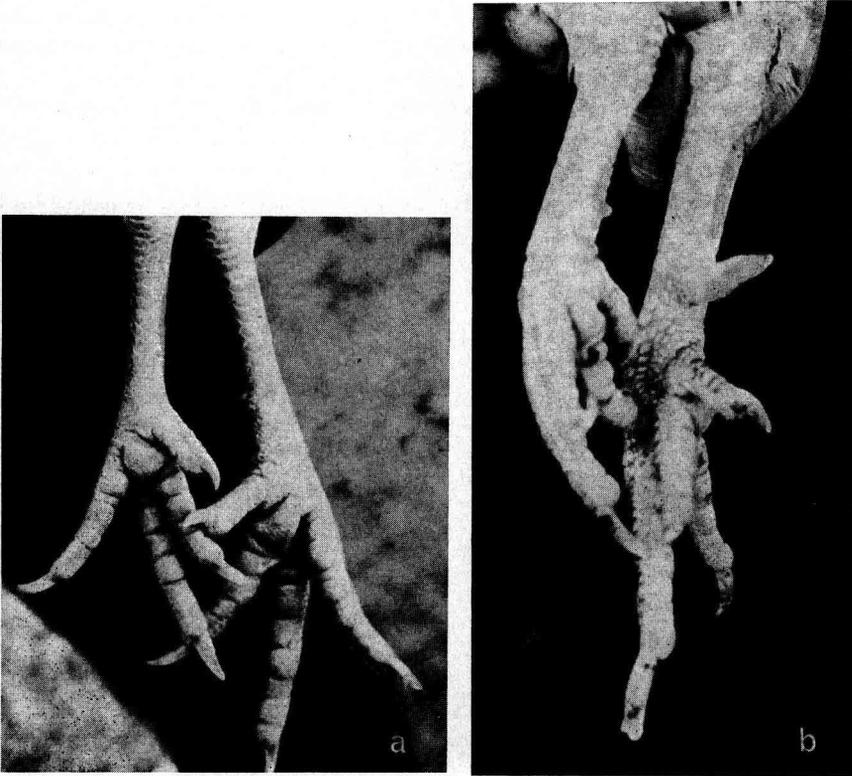


FIG. 1. — *Legs of mosaic female*

- a) First observed at 16 weeks of age. Note spur bud and larger scales on right shank.  
 b) When three years of age with very well developed spur on right shank. Right shank 12 cm long and left shank 9 cm long.

*Pattes de la femelle mosaïque*

- a) Observées à 16 semaines d'âge. Noter le bourgeon d'ergot et les écailles plus grandes sur la patte droite.  
 b) A l'âge de 3 ans, avec un ergot bien développé sur le tarse droit. Tarse droit ayant 12 cm de long et tarse gauche 9 cm.

The hypothesis we favor is that the polar body carrying the large sex chromosome,  $Z^+$ , and therefore the dominant sex linked gene for normal body size, since the dam was a normal-size female, reunited with half the zygote after the first cleavage. This would result in triploidy for the autosomes and diploidy for the  $Z$  sex chromosome on the normal side,  $AAAZ^+Z^{aw}$ , and simple diploidy on the dwarf side, or  $AAZ^{aw}W$ .

The second possibility, suggested by Dr R. N. SHOFFNER, is that of non-disjunction of the  $ZW$  at the first metaphase (first polar body extrusion) resulting in the

female gamete with a set of autosomes, A, and  $Z^+W$  sex chromosomes. This female gamete,  $AZ^+W$ , fertilized by a dwarf male gamete,  $AZ^{dw}$ , would result in a zygote diploid for autosomes but trisomic for the sex chromosomes,  $AAZ^+Z^{dw}W$ . At the first or possibly some very early cleavage the chance segregation of the sex chromosomes could be  $Z^{dw}W$  to one daughter cell and  $Z^+O$  to another daughter cell which followed by unilateral proliferation of these cells would result in one side,  $Z^{dw}$ , being dwarf as well as a genetic female, while the other side,  $Z^+O$ , would be a genetic « neuter » of normal size. The endocrine control would originate from the left functional gonad or ovary. These two possible explanations are illustrated in fig. 2.

The critical observation will of course be to determine the karyotype of the mosaic on each of its two sides. So far a limited study of feather follicles and of blood cell cultures have not shown departure from the normal female karyotype of  $ZW$ . We plan a detailed cytological study whenever we undertake an autopsy on this mosaic bird.

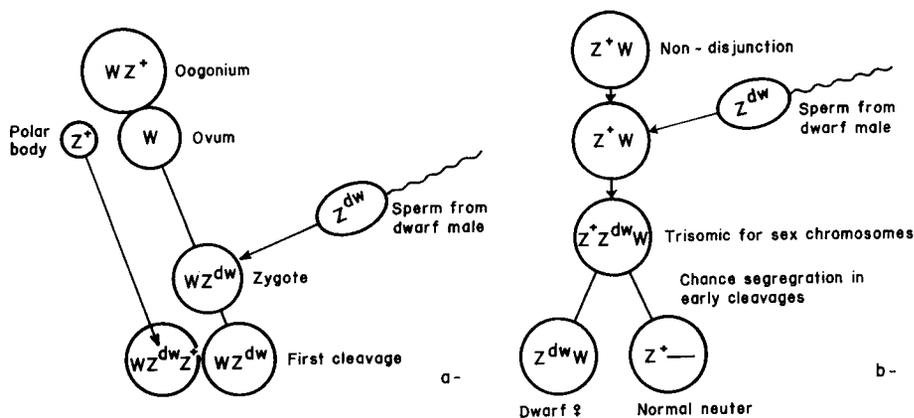


FIG. 2. — Possible explanations for the dwarf-normal mosaic female obtained from the mating of a dwarf male and a normal female

- a) Reunion of polar body with first cleavage product.
- b) Non-disjunction at Metaphase I in oogenesis.

*Explications possibles de la femelle mosaïque naine-normale obtenue à partir de l'accouplement d'un mâle nain et d'une femelle normale*

- a) Réunion du globe polaire avec le produit du premier clivage.
- b) Non-disjonction à la Métaphase I dans l'ovogenèse.

### SEX-LINKED RECESSIVE LETHAL

In our genetic selection in the dwarf line, in 1961, we observed a sex-linked recessive lethal which probably would have gone unnoticed had it not been for [some unusual circumstance. Earlier we referred to the fact that we innocently had mixed birds possibly carrying hypothyroidism and sex-linked recessive dwarfism. As our intensive selection program progressed we necessarily inbred and this resulted in the segregation of the polygenes for hypothyroidism. These segregates were manifestly poorer layers and many were non-layers while the males were often obese and difficult if not impossible to ejaculate. Chance favored us with a male that was an

exceptionally heavy semen producer as well as easy to ejaculate. This male was used extensively in inseminating 50 dams and it sired 437 chicks. Throughout the brooding season we noted that there appeared to be an unusually large number of red combs in that brood of chicks. It turned out that the sex distribution was 297 males and 140 females or 68 : 32 or very close to the 2 : 1 ratio expected on the basis of a sex-linked recessive lethal. The affected female zygotes apparently die very early, so early that it is often difficult to identify the egg as infertile or as early dead. It has not been possible as yet to determine the relationship of this sex-linked recessive lethal to the gene for dwarfism. Male # 6 266 was also heterozygous for the spontaneous chromosome translocation we have described earlier, BERNIER (1953, 1960) and RYAN and BERNIER (1968), and it is likely that this heterozygosity may explain the excellent semen production. Table 2 shows the results obtained with male #6 266.

TABLE 2

*A sex-linked recessive lethal in a dwarf male  
no. 6266, observed in 1961*

*Un létal récessif lié au sexe chez un mâle nain  
n° 6266, observé en 1961*

	Number	Percentage	
No. of mates .....	50		F
No. of eggs set .....	1 314		F
No. of infertile .....	334	74.6 fertility	F
No. of dead embryos { (D <sub>1</sub> ) * .....	473 *	48.3 of fertile eggs	
{ (D <sub>2+3</sub> ) .....	70	7.1 of fertile eggs	
No. of chicks .....	437	30.1 of all eggs	
		44.6 of fertile eggs	
No. of male chicks .....	297	68.0 of all chicks or 2 · 125 : 1	
No. of female chicks .....	140	32.0 of all chicks	

\* This male was also heterozygous for the OSU spontaneous chromosome translocation which explains the 48.3 p. 100 of early dead embryos.

## REPRODUCTION

We can now report on reproduction in different types of matings. First, when dwarf females are produced by mating dwarf males with normal females, we indicated earlier this is how we produce the females needed in the nutrition studies. It is the easiest method to produce dwarf stock in a large breeding organization. Only a small number of males need to be bred to allow the production of a very large number of dwarf pullets. Results over a period of years are illustrated in table 3.

The first year of this program in 1965 we did not have a sufficient number of males to mate in natural matings with the females available and necessary to produce the number of pullets required. We therefore resorted to artificial insemination.

In 1966 the number of males was again insufficient but we decided to use the small number available in groups that we rotated from pen to pen every three days with a period of three days in each cycle of nine days without males. In 1967 we had enough

TABLE 3

*Fertility and hatchability in matings of dwarf males with normal-size females*

*Taux de fertilité et d'éclosion dans des accouplements de mâles nains et de femelles de taille normale*

Year	1965	1966	1967	1968	1969	1970 a	1970 b	1971 a	1971 b
No. pens .....	12	6	16	9	6	9	9	6	6
Hens per pen .....	50	50	50	50	45	80	80	80	80
Males per pen .....	A. I.	rotation 5-0-3	3	5	4	8	8	8	8
Male : females ....	—	—	≈ 1 : 15	≈ 1 : 10	≈ 1 : 10	≈ 1 : 10	≈ 1 : 10	≈ 1 : 10	≈ 1 : 10
No. of eggs .....	2 490	3 027	2 400	3 541	3 686	2 426	4 300	1 258	4 049
Fertility p. 100 ...	—	80.5	80.8	84.8	41.9	75.1	88.7	93.4	97.8
Hatch p. 100 :									
All eggs .....	81.3	70.2	75.5	74.0	38.7	70.0	75.0	79.7	82.9
Fertile eggs .....	—	87.2	93.4	87.3	92.4	93.2	84.5	85.3	84.8

males to mate in the ratio of 1 : 15 but the fertility (80.8 p. 100) was not considered satisfactory. In 1968 and since, the male-female ratio was lowered to 1 : 10 but only this year in 1971 has fertility reached a high level and rapidly enough to be considered satisfactory. What may be a simple explanation for this improvement is that until this year the males, kept in the dark to reduce fighting, were moved directly from dark holding pens to the breeding pens. Apparently it took a period of time for them to produce satisfactory amounts of semen, to adjust to their new surroundings and to mate with all the females. This year we moved the males from darkness to a lighted pen approximately one month before they were to be placed with the hens. We have plotted the rate of increase in fertility in the different years in the different pens and the results are illustrated in fig. 3 a-3 e.

TABLE 4

*Fertility and hatchability in dwarf and in normal matings*

*Taux de fertilité et d'éclosion dans les accouplements de nains ou de normaux*

Type	1966		1967		1968		1969		1970	
	Normal	Dwarf	Normal	Dwarf	Normal	Dwarf	Normal	Dwarf	Normal	Dwarf
Mating .....	Natural	A. I.	A. I.	A. I.						
Eggs .....	1 783	1 553	1 784	1 101	1 649	1 360	2 538	1 601	2 244	1 639
% fertility ..	84.3	87.6	92.0	91.3	92.5	94.0	67.7	95.4	84.7	89.3
% hatch FE.	84.9	89.0	88	88.3	77.8	91.1	87.0	86.3	82.9	85.0

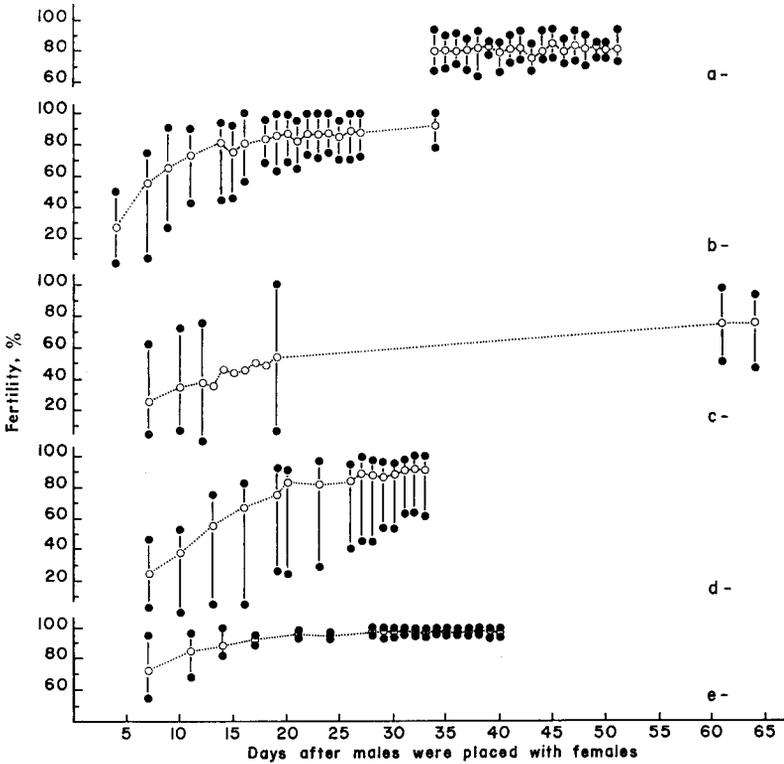


FIG. 3. — Onset and level of fertility in natural matings of dwarf males with normal-size hens

The averages are represented by ○ and the range by ●

- a) 6 pens of 50 females. Groups of 5 and 3 males rotated every three days with a period of three days without males (1966).
- b) 9 pens of 50 females. 5 males per pen or □ 1 : 10 (1968).
- c) 6 pens of 45 females. 4 males per pen or □ 1 : 10 (1969).
- d) 9 pens of 80 females. 8 males per pen or □ 1 : 10 (1970).
- e) 6 pens of 80 females. 8 males per pen or □ 1 : 10 (1971).

*Établissement et niveau de la fertilité dans les accouplements naturels de mâles nains avec des poules de taille normale*

Les moyennes sont représentées par ○ et les intervalles de variation par ●

- a) 6 parquets de 50 femelles. Groupes de 5 et 3 mâles en rotation tous les trois jours avec une période de trois jours sans mâles (1966).
- b) 9 parquets de 50 femelles. 5 mâles par parquet ou □ 1/10 (1968).
- c) 6 parquets de 45 femelles. 4 mâles par parquet ou □ 1/10 (1969).
- d) 9 parquets de 80 femelles. 8 mâles par parquet ou □ 1/10 (1970).
- e) 6 parquets de 80 femelles. 8 mâles par parquet ou □ 1/10 (1971).

As indicated earlier we are now satisfied that good fertility can be obtained in matings of dwarf males and normal females but we would like to increase, if possible, the 1 : 10 male-female ratio we have used in recent years. We have no explanation for the low fertility observed in 1969 not only in these dwarf-normal matings but also in our regular matings as we note in Table 4 other than some lighting problem which one cannot identify more completely.

Second, dwarf birds can of course be reproduced as a line which we can submit

to selection for economic traits. Table 4 shows the fertility and hatchability observed in recent years in our selection program in the dwarf and in the normal size lines for comparative purposes. It is evident that the reproductive performance of our dwarf line is comparable to that of our normal size Production Line.

### GENETIC SELECTION

Observations on our dwarf layers in the first few years revealed that their principal defects were delayed sexual maturity, smaller eggs and lower egg production. Limited facilities did not allow us to test as many families as would have been desirable, so we compromised. We raised more dwarf pullets than we had room to test for the entire production period and we placed heavy selection pressure on sexual maturity and on initial egg size. We rigorously culled individuals and families that matured late and that laid small eggs. Although a convenient compromise it unfortunately prevented us from obtaining comparative performance data in the early years except in the nutrition investigations. In more recent years we have been able to

TABLE 5

*Hen-housed performance of normal and dwarf layers at 40 weeks of age*  
*Performances rapportées aux poules logées pour des pondeuses normales et naines*  
*à 40 semaines d'âge*

Year	Type	Number	S. M. wks	H. H. eggs	Body weight		Egg wt. Dec. (g)	Livability (%)
					10 wks	20 wks		
					(lbs)			
1970-71*	<i>Dw</i> .....	628	22.6	102.2	1.8	3.1	58.7	96.7
	<i>dw</i> .....	819	24.3	85.2	1.4	2.3	55.7	94.3
	<i>dw Dw</i> (100)		107.5	83.4	77.8	74.2	94.9	97.5
1969-70*	<i>Dw</i> .....	644	24.2	88.7	1.5	3.4	57.6	97.2
	<i>dw</i> .....	582	25.9	72.4	1.2	2.4	55.1	96.2
	<i>dw Dw</i> (100)		107.0	81.6	80.0	70.6	95.7	99.0
1968-69*	<i>Dw</i> .....	489	25.0	74.3	1.7	3.1	53.9	91.0
	<i>dw</i> .....	494	27.7	51.3	1.2	—	51.1	95.3
	<i>dw Dw</i> (100)		110.8	69.0	70.6	—	94.8	104.7
1967-68**	<i>Dw</i> .....	449	21.9	43.0	1.8	2.8	57.0	95.3
	<i>dw</i> .....	382	28.7	23.4	1.3	—	53.8	98.4
	<i>dw Dw</i> (100)		131.0	54.4	72.2	—	94.4	103.3
1966-67**	<i>Dw</i> .....	458	21.5	46.2	1.9	3.0	55.7	97.2
	<i>dw</i> .....	400	32.5	10.6	1.3	2.1	52.3	95.5
	<i>dw Dw</i> (100)		151.1	22.9	68.4	70.0	93.9	98.3
1965-66**	<i>Dw</i> .....	519	22.2	46.1	1.7	2.9	56.1	95.8
	<i>dw</i> .....	240	27.9	20.0	1.4	—	53.2	91.7
	<i>dw Dw</i> (100)		125.6	43.4	82.4	—	94.8	95.7

\* Full trapnesting.

\*\* 3-day a week trapnesting.

allocate more cage space to the dwarf selection program and we can report on the relative performance of the dwarf line and of our OSU Production Line. Table 5 gives those comparative data for recent years.

Sexual maturity (SM) expressed in weeks was as high as 32.5 weeks in the dwarf line in 1966-67 but it has gradually decreased to 24.3 weeks in the current generation which is only 1.7 weeks later than that of our OSU Production Line.

Hen-housed egg production (HH) which was disappointingly low in 1965-66, 1966-67, and 1968-69, began to show improvement in 1968-69 and in the current generation it is 83.4 p. 100 as high as that observed in the OSU Production Line. We should perhaps indicate that the dwarf layers in this selection project are fed a commercial complete breeder 15 p. 100 protein ration which we have shown in our nutrition investigations to be inadequate in protein or methionine for them. This inadequacy provides an additional stress factor which hopefully increases the sensitivity of our selection.

Body weight as measured at 10 and at 20 weeks of age, when the layers are housed, has not changed in the dwarf layers but only because of the restriction placed on it in our selection. It would very likely have increased as a result of a correlated response to our selection for egg size. We have not always been able to measure body weight of all the dwarf layers at 20 weeks because of the limited housing facilities in prior years.

Egg size, as we have indicated earlier, is critical for dwarf layers and we have placed emphasis on this trait in our selection. We are making progress and the fact, as demonstrated by FESTING and NORDSKOG (1967), that egg size can be manipulated somewhat independently of body weight and which is so well demonstrated historically in the modern *Leghorn* is certainly justification for optimism.

Livability in the dwarf line has usually been superior to that observed in our OSU Production Line.

#### NUTRITION STUDIES

Our nutrition studies began in 1958 with the association of GHA with the research project. That first year we placed 120 dwarf and 120 of their normal size sisters in individual cages. We kept individual records of feed consumption, of all eggs produced and of their weight. We compared the effects of two calcium-phosphorus levels (3.0 p. 100 Ca-0.9 p. 100 P and 2.25 p. 100 Ca-0.6 p. 100 P) on corn-soybean meal-fish meal rations, with similar calorie protein ratios (84.9-87.1), containing 15 p. 100 protein with either the normal or double that level of a vitamin trace mineral supplement (DVTMS) and 18 p. 100 protein with double the normal vitamin trace mineral supplementation. These results were reported by ARSCOTT, RACHAPAETAYAKOM and BERNIER (1961) and are summarized in table 6. The additional calcium and phosphorus improved egg production and shell quality of dwarf layers more than those of their normal sisters. The additional vitamin trace mineral supplementation also benefited egg production and shell quality in the dwarf layers. The 18 p. 100 protein level did not bring an improvement in egg production but it resulted in a marked decrease in feed intake which may have masked the possible improvement in egg production. Egg weight was not affected by any of the treatments.

TABLE 6

*Observations on gross requirements for certain nutrients  
in dwarf White Leghorn hens*

ARSCOTT, RACHAPAETAYAKOM and BERNIER (1961)

*Observations sur les besoins globaux en certains nutriments  
pour des poules Leghorn blanches naines*

ARSCOTT, RACHAPAETAYAKOM et BERNIER (1961)

Type of layers	Treatment		Body wt. (lb)	Eggs (bs.)	Feed consumed (lb/bird)	Egg wt. (g)	Spec. gravity $\times 10^3$ — 1 000
Normal	Ca %	P %					
	2.25	0.6	4.51	13.7	6.15	60.5	78.7
Dwarf	3.00	0.9	4.55	14.4	6.40	61.0	80.3
	2.25	0.6	2.89	11.2	3.97	53.9	73.8
Normal	3.00	0.9	2.95	12.9	4.30	54.6	77.0
	15 % protein		4.66	14.4	6.58	61.2	79.2
Dwarf	+ DVTMS		4.49	14.2	6.73	61.0	80.4
	18 % protein						
Normal	+ DVTMS		4.62	13.6	5.53	60.5	79.0
	15 % protein		2.88	11.7	4.22	54.6	75.0
Dwarf	+ DVTMS		2.95	12.3	4.47	54.3	76.8
	18 % protein						
	+ DVTMS		2.94	12.2	3.70	53.9	74.5

TABLE 7

*Influence of ascorbic acid, calcium and phosphorus on performance  
of normal size and dwarf White Leghorn hens*

ARSCOTT, RACHAPAETAYAKOM, BERNIER and ADAMS (1962)

*Influence de l'acide ascorbique, du calcium et du phosphore  
sur les performances de poules Leghorn blanches de taille normale ou naines*

ARSCOTT, RACHAPAETAYAKOM, BERNIER and ADAMS (1962)

Type of layer	Treatment			Egg spec. gravity	Blood		Egg prod. (%)	Egg wt. (g)
	Ca %	P %	Vit. C (mg/lb)		Ca	P		
					(mg %)			
Normal	2.25	0.6	0	1.075 7	28.7	4.6	60.5	59
	2.25	0.6	10	1.076 7	27.6	4.4	66.9	58
	3.00	0.6	0	1.078 1 *	30.5 *	4.9 *	69.7	59
	2.25	0.9	0	1.074 3 *	28.2	5.4 *	73.6	59
Dwarf	2.25	0.6	0	1.068 4	—	—	37.1	57
	2.25	0.6	10	1.068 9	—	—	33.8	58
	3.00	0.6	0	1.073 4 *	—	—	41.4	58

\* Significantly different from control  $P < .05$ .

Our next two experiments conducted in 1961 and 1962 compared different levels of calcium and have not been reported as yet. In general they confirm the results obtained in the first experiment showing improved shell quality from higher calcium levels.

In our third investigation we studied the influence of ascorbic acid, calcium and phosphorus on egg shell quality as measured by specific gravity. This experiment was reported by ARSCOTT, RACHAPAETAYAKOM, BERNIER and ADAMS (1962) and the

TABLE 8

*Growth and feed requirements of dwarf White Leghorn pullets compared to their normal-size sisters*

Body weights (g)  
BERNIER and ARSCOTT (1966)

*Croissance et besoins alimentaires de poulettes Leghorn blanches naines comparées à leurs sœurs de taille normale*

Poids corporels (g)  
BERNIER et ARSCOTT (1966)

Type	Weeks				
	4	8	12	17	23
Normal.....	289	641	1 006	1 224	1 464
Dwarf .....	218	460	706	896	1 029
$\frac{\text{Dwarf}}{\text{Normal}} \times 100$ .....	75.4	71.8	70.2	73.2	70.3

TABLE 9

*Growth and feed requirements of dwarf White Leghorn pullets compared to their normal-size sisters*

Feed consumption (g)  
BERNIER and ARSCOTT (1966)

*Croissance et besoins alimentaires de poulettes Leghorn blanches naines comparés à leurs sœurs de taille normale*

Consommation alimentaire (g)  
BERNIER et ARSCOTT (1966)

Type	Weeks				
	4	8	12	17	23
Normal.....	499	1 669	3 280	5 670	8 634
Dwarf .....	365	1 168	2 221	3 949	5 838
$\frac{\text{Dwarf}}{\text{Normal}} \times 100$ .....	73.1	70.0	67.7	69.6	67.6

results are illustrated in table 7. No improvement in egg shell thickness was apparent with either normal size or dwarf *White Leghorn* fed rations containing ascorbic acid. A marked improvement in shell thickness, accompanied by an increase in blood calcium and phosphorus, was obtained in normal size birds in the presence of 3 p. 100 calcium and a similar improvement in shell thickness was obtained with the dwarfs fed the rations containing 3 p. 100 calcium. Increasing the phosphorus level to 0.9 p. 100 appeared to reduce shell thickness and to increase blood phosphorus. This latter observation has since been reported by others.

TABLE IO

*Growth and feed requirements of dwarf White Leghorn pullets compared to their normal-size sisters*

Feed conversion  
BERNIER and ARSCOTT (1966)

*Croissance et besoins alimentaires de poulettes Leghorn blanches naines comparées à leurs sœurs de taille normale*

Indice de conversion  
BERNIER et ARSCOTT (1966)

Type	Weeks				
	4	8	12	17	23
Normal.....	1.73	2.61	3.26	4.63	5.90
Dwarf .....	1.67	2.54	3.14	4.41	5.68

TABLE II

*Growth and feed requirements of dwarf White Leghorn pullets compared to their normal-size sisters*

Cumulative mortality (%)  
BERNIER and ARSCOTT (1966)

*Croissance et besoins alimentaires de poulettes Leghorn blanches naines comparées à leurs sœurs de taille normale*

Mortalité cumulée (%)  
BERNIER et ARSCOTT (1966)

Type <sup>(1)</sup>	Weeks			
	4	8	12	17
Normal.....	1.7	4.4	8.4	10.9
Dwarf .....	6.6	7.1	9.0	9.7

<sup>(1)</sup> 700 chicks of each type at start.

In our fourth nutrition investigation we measured the growth and feed requirements of developing dwarf pullets compared to their normal size sisters. We used two populations of 700 day old chicks of each type which were each brooded in duplicate groups. Both types of birds were fed the same rations. During the first 8 weeks they were fed a high energy corn-soybean meal-5 p. 100 fish meal starter diet with 20 p. 100 protein and 1 370 kcal. metabolizable energy/lb. From the eighth through the 23rd week the birds were fed a medium energy corn-barley-soybean meal-2 p. 100 fish meal grower diet with 14.9 p. 100 protein and 1 285 kcal. metabolizable energy/lb. Body weight and feed consumption were recorded at 4-6 week intervals. The results were reported by BERNIER and ARSCOTT (1966) and are illustrated in Tables 8 and 9 and fig. 4 *a-4 b* for both body weight and feed consumption. Feed conversion as shown in table 10 consistently favored the dwarf pullets. Mortality, Table 11, was heavier in the first 8 weeks of life in the dwarfs possibly because they were not rigidly culled at hatching time because of limited numbers. Table 12 illustrates the fact that even after allowing for the delayed sexual maturity of the dwarf pullets they still required much less feed to reach laying age.

TABLE 12

*Growth and feed requirements of dwarf White Leghorn pullets compared to their normal-size sisters*

Data recalculated for time required to reach 25 p. 100 egg production  
BERNIER and ARSCOTT (1966),

*Croissance et besoins alimentaires de poulettes Leghorn blanches naines comparées à leurs sœurs de taille normale*

Données recalculées d'après le temps requis pour atteindre 25 p. 100 de ponte  
BERNIER et ARSCOTT (1966)

	Body wts. (g)	Feed Cons. (g)
Normal : 23 wks. ....	1 464	8 634
Dwarf : 25 wks. ....	1 094	6 302
$\frac{\text{Dwarf}}{\text{Normal}} \times 100$ .....	74.7	73.0

Our fifth investigation involved two experiments comparing the development and feed requirements of developing dwarf pullets fed a 20 p. 100 protein starter for the first four or the first eight weeks followed in both instances by a 15 p. 100 protein developer. The results have not been published as yet but they are satisfactory and furthermore the egg production of the pullets is not impaired by the lower protein level fed during the development period.

The sixth investigation compared different protein levels in two separate 280-day periods using corn-soybean meal base diets for the dwarf layers, supplemented by higher calcium and vitamin trace mineral levels than those fed the normal layers-3.7 p. 100 vs. 2.8 p. 100 Ca and 0.33 p. 100 vs. 0.25 p. 100 vitamin trace mineral

supplement respectively. The protein levels ranged from 12 to 21 p. 100 for the dwarf layers and from 12 to 18 p. 100 for their normal sisters. The results of these two experiments have been reported by ARSCOTT and BERNIER (1968) and BERNIER and ARSCOTT (1968) and are shown in Tables 13-16. Egg production and feed per dozen

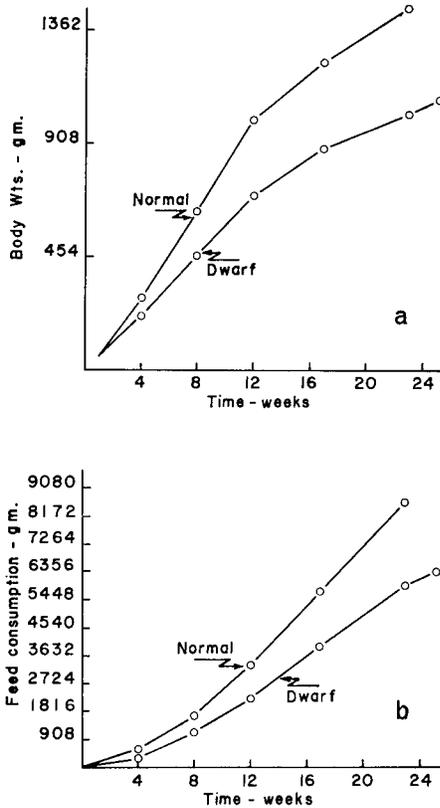


FIG. 4. — Growth and feed requirements of dwarf White Leghorn pullets compared to their normal-size sisters (BERNIER and ARSCOTT, 1966)

- a) Body weight.  
b) Feed consumption.

*Croissance et besoins nutritionnels de poulettes Leghorn blanches naines comparées à leurs sœurs de taille normale* (BERNIER et ARSCOTT, 1966)

- a) Poids corporels.  
b) Consommation alimentaire.

eggs for the dwarfs both plateaued at the 15 p. 100 level of protein while in normals this occurred at 14 p. 100. The dwarfs laid 13 p. 100 fewer eggs but the feed required per dozen eggs was 18 p. 100 less than in normals. Egg size increased with protein levels to 21 p. 100 in dwarfs but in normals it plateaued at 16 p. 100 protein. Feed consumption of dwarfs increased with protein levels in Experiment 1 but it plateaued at 15 p. 100 in Experiment 2. Dwarfs fed 21 p. 100 protein had a protein intake of

17.3 grams while normals had a protein intake of 17.2 grams when fed 16 p. 100 protein. The addition of .05 p. 100 dl-methionine to the 12 p. 100 protein diet of dwarfs increased egg weight significantly but .05 p. 100 lysine was without effect.

TABLE 13

*Effect of protein level on egg production*  
 Av. ten 28-day periods  
 ARSCOTT and BERNIER (1968)  
 BERNIER and ARSCOTT (1968)

*Effet du taux protéique sur la production d'œufs*  
 Moyenne de dix périodes de 28 jours

Prot. level (%)	Egg prod. (%) (hen day)	
	Exp't 1	Exp't 2
	<i>Dwarf</i>	
12 + <i>meth</i> + ( <i>lys</i> )	41.0 <sup>a</sup> + 42.8 <sup>a</sup>	49.8 <sup>a</sup> + (51.9 <sup>a</sup> )
14	48.5 <sup>b</sup>	—
15	—	60.2 <sup>b</sup>
16	56.7 <sup>c</sup>	—
18	60.0 <sup>c</sup>	59.9 <sup>b</sup>
21	—	60.8 <sup>b</sup>
	<i>Normal</i>	
12	60.8 <sup>cd</sup>	—
14	68.5 <sup>e</sup> *	—
16	65.9 <sup>e</sup> *	69.2 <sup>c</sup>
18	69.3 <sup>e</sup> *	—

<sup>1</sup>. Different letters within exp'ts indicate sig. differences ( $p < .01$ ).

\* ( $p < .05$ ).

Our last reported nutrition investigation also involved two experiments each of ten 28-day periods and in which a ration of 15.2 p. 100 protein, with and without different levels (.025, .05, .1 p. 100) of dl-methionine, a level (.05 p. 100) of lysine and a level (2 p. 100) of safflower oil, alone and in combination, as well as a ration containing 20.9 p. 100 protein, were fed to duplicate lots of dwarf layers and compared to a ration of 15.8 p. 100 protein fed to duplicate lots of normals. This study was reported by ARSCOTT and BERNIER (1970) and table 17 shows that in Experiment 1 only the higher protein level resulted in a significant improvement in egg production of the dwarfs although .05 p. 100 dl-methionine resulted in an intermediate response. In Experiment 2 no difference was observed between the two protein levels or the various levels of methionine or combinations of methionine (.05 p. 100), lysine and safflower oil. There was a tendency towards higher production in the presence of .05 p. 100 methionine or 20.9 p. 100 protein.

Table 18 shows that in Experiment 1 the addition of .05 p. 100 dl-methionine and the 20.9 p. 100 protein ratios both brought about a significant increase in egg weight. In Experiment 2 increasing levels of methionine resulted in increased egg weight but only the .1 p. 100 level of methionine showed a significant improvement over the negative control. The dwarf group fed the 20.9 p. 100 protein diet also laid significantly larger eggs than the control group. Combinations involving .05 p. 100

TABLE 14

*Effect of protein level on egg weight*

Av. ten 28-day periods  
ARSCOTT and BERNIER (1968)  
BERNIER and ARSCOTT (1968)

*Effet du taux protéique sur le poids de l'œuf*

Moyenne de dix périodes de 28 jours

Prot. level (%)	Egg wt. (g)	
	Exp't 1	Exp't 2
	<i>Dwarf</i>	
12 + <i>meth</i> + ( <i>lys</i> )	48.2 <sup>a</sup> + 51.1 <sup>bc</sup>	50.9 <sup>a</sup> + (51.7 <sup>ab</sup> )
14	50.1 <sup>b</sup>	—
15	—	52.7 <sup>bc</sup>
16	51.6 <sup>c</sup>	—
18	53.5 <sup>d</sup>	54.0 <sup>e</sup>
21	—	55.7 <sup>d</sup>
	<i>Normal</i>	
12	56.8 <sup>e</sup>	—
14	57.0 <sup>ef</sup>	—
16	58.1 <sup>f</sup> *	58.0 <sup>e</sup>
18	58.2 <sup>f</sup> *	—

<sup>1</sup>. Different letters within exp'ts indicate sig. differences ( $p < .01$ ).  
\* ( $p < .05$ ).

dl-methionine and 2 p. 100 safflower oil with or without .05 p. 100 l-lysine also brought about a significant improvement in egg weight.

Table 19 shows the effect of protein level and supplements on feed per dozen eggs. The normals produced eggs less efficiently than the dwarfs. The most efficient performance was that of dwarfs fed the supplement of .05 p. 100 dl-methionine in Experiment 2. The various treatments had no significant effect on final body weight of dwarfs. Normals weighed significantly more than dwarfs or 3.9 pounds as compared to 3.0 pounds.

It thus seems that supplementation of a 15.2 p. 100 protein diet with .05 and .1 dl-methionine improved egg production and egg weight in dwarfs to levels comparable to those observed with the 20.9 p. 100 protein diet. However, dwarfs still

TABLE 15

Calculated daily protein intake in relation to dietary protein level

ARSCOTT and BERNIER (1968)

BERNIER and ARSCOTT (1968)

Ingestion journalière de protéines calculée en relation avec  
le taux protéique de la ration

Prot. level (%)	Daily prot. intake * (g)	
	Exp't 1	Exp't 2
	<i>Dwarf</i>	
12 + meth + (lys)	8.0 + 8.4	9.0 + (9.4)
14	10.2	—
15	—	12.1
16	12.2	—
18	14.5	14.5
21	—	17.3
	<i>Normal</i>	
12	14.3	—
14	16.2	—
16	18.3	17.2
18	20.4	—

\* Based on calculated prot. content to nearest tenth.

TABLE 16

Effect of protein level on feed per dozen eggs

Av. ten 28-day periods

ARSCOTT and BERNIER (1968)

BERNIER and ARSCOTT (1968)

Effet du taux protéique sur la consommation par douzaine d'œufs pondus  
moyenne de dix périodes de 28 jours

Prot. level (%)	Feed/doz eggs (lb)	
	Exp't 1	Exp't 2
	<i>Dwarf</i>	
12 + meth + lys	4.52 <sup>a</sup> + 4.43 <sup>ab</sup>	3.94 <sup>a</sup> + (3.92 <sup>a</sup> )
14	4.03 <sup>b</sup>	—
15	—	3.51 <sup>b</sup>
16	3.68 <sup>c</sup>	—
18	3.66 <sup>c</sup>	3.55 <sup>b</sup>
21	—	3.63 <sup>b</sup>
	<i>Normal</i>	
12	5.11 <sup>a</sup>	—
14	4.54 <sup>a</sup>	—
16	4.69 <sup>aa</sup>	4.24 <sup>c</sup>
18	4.44 <sup>ab</sup>	—

(<sup>1</sup>) Different letters within exp'ts indicate sig. differences ( $p < .01$ ).

laid fewer and smaller eggs than their normal size sisters although there was progress attributable to both genetic and nutrition influences.

We have conducted an additional experiment on supplementation of a 15 p.100 protein diet for dwarfs with levels of up to 0.15 p. 100 methionine which has not been reported yet. There was no apparent beneficial effect from levels above 0.05 p. 100 dl-methionine. Fish meal at the level of 3 p. 100 apparently meets the increased requirement for methionine in the diet of dwarf layers.

Currently we are conducting an experiment comparing diets based on different cereals with and without a supplement of 0.033 p. 100 Protamone. Dwarf pullets fed diets supplemented with Protamone grew faster and ate more in the first four weeks than even normal size pullets but the effect gradually decreased and was negligible at 16 weeks of age. The level of 0.033 p. 100 Protamone in the diet of layers depressed egg production and was subsequently reduced by one half.

### PHYSIOLOGY

In the early years of our work with dwarfs we realized that a better understanding of their physiology, more specifically, the hormonal factors involved, would more precisely define their potential. We therefore undertook some studies with the kind cooperation of a colleague endocrinologist in the Department of Animal Science, Dr E. F. ELLINGTON, now at the University of Nebraska. The studies were begun in 1966 and when completed the results were presented as a thesis by one of our graduate students, Mr. L. W. MIROSH, (1967) recipient of the Chester M. Wilcox Memorial Fellowship in Poultry Science. Two manuscripts incorporating the major results will be submitted for publication shortly (MIROSH, BERNIER, ELLINGTON, ARSCOTT and ROWE, 1971). The study was conducted on 19 normal size and 21 dwarf pullets 2-3 months of age and 20 normal and 20 dwarf pullets 7-13 months of age. It was in two parts. One involved measurements of various endocrine glands and certain anatomical structures as shown in Tables 20-22. The second part involved the bioassay of the hypophyses of both types of birds at the two ages using hypophysectomized rats and the results are reported in Tables 23-25.

Normal chickens in both age groups were found to have significantly heavier hypophyses, thyroids, adrenals and ovaries than the dwarfs. These differences tended to disappear when the endocrine weights were expressed as a function of body weight, either absolute or metabolic body weight, except for the following instances. The relative weight of the hypophysis was significantly smaller in the older normals than in the other three groups of birds which could also indicate that the older dwarfs had a larger than expected hypophysis on a relative basis. The adrenals were significantly heavier in the older normals than in the other three groups which would indicate that the dwarfs did not have as large adrenals as would be expected. The relative weight of the thyroid was significantly heavier in the older normals than in the young normals while the reverse held for the dwarfs which had a relatively smaller thyroid as they grew older. The weight of the thyroid in the normal chickens almost doubled as they passed from the 2-3 month to the 7-13 month stage while that of the

TABLE 17

*Effect of protein, dl-methionine (Met), l-lysine (Lys)  
and safflower oil (SO) on egg production*

ARSCOTT and BERNIER (1970)

*Effet des protéines, de la dl-méthionine (Met.), de l-lysine (Lys.)  
et de l'huile de cathame (SO) sur la production d'œufs*

ARSCOTT et BERNIER (1970)

Prot., amino acid and/or SO (%)	Egg prod. (hen day) (%)	
	Exp't 1	Exp't 2
<i>Dwarf</i>		
15.2 .....	53.7 <sup>a</sup> *	55.8 <sup>a</sup>
15.2 + .025 met. ....		56.8 <sup>a</sup>
15.2 + .05 met. ....	57.0 <sup>ab</sup>	60.0 <sup>a</sup>
15.2 + .1 met. ....		59.0 <sup>a</sup>
15.2 + .05 lys. ....	53.0 <sup>a</sup>	
15.2 + 2 SO .....	53.6 <sup>a</sup>	
15.2 + .05 met. + .05 lys. ....		57.6 <sup>a</sup>
15.2 + .05 met. + 2 SO .....		55.9 <sup>a</sup>
15.2 + .05 met. + .05 lys. + 2 SO .....		58.8 <sup>a</sup>
20.9 .....	59.2 <sup>b</sup>	58.6 <sup>a</sup>
<i>Normal</i>		
15.8 .....	64.1 <sup>c</sup>	65.5 <sup>b</sup> **

\* Treatments with different letters are significantly different (P < .05).

\*\* Significantly different (P < .01) than from dwarfs combined.

dwarfs changed very little which would lead to the hypothesis of hypothyroidism. This hypothesis is also supported by the histological characteristics of the thyroid. The epithelial cell height of the older dwarfs was significantly lower than that of the older normals and the young chickens of both types. The diameter of the colloid and the follicle were significantly higher in normals than in dwarfs of both ages.

It is tempting to explain sex-linked [recessive dwarfism by hypothyroidism. However the finding that such dwarfism is not overcome by the feeding of iodinated casein (van TIENHOVEN *et al* 1966 ; BERNIER, 1965, unpublished) nor by the injection of thyroxin (BERNIER, 1965, unpublished) would argue against hypothyroidism as the principal or sole factor involved. Notwithstanding these facts hypothyroidism as an explanation for sex-linked recessive dwarfism gains support from the histology of the thyroid as observed in this study and that of van TIENHOVEN *et al.* (1966). More recently, MÉRAT and GUILLAUME (1969) have reported smaller thyroids relative to body weight, a lower metabolism, reduced thyroid secretion, a higher percentage of abdominal fat, and a calmer disposition in dwarf birds than in normal size birds which led them to hypothesize hypothyroidism as associated with sex-linked recessive dwarfism. Whether or not alterations in pituitary thyrotropic activity are responsible

for the thyroid disturbances observed in dwarfs could not be fully ascertained from the bioassay results of the hypophyses with hypophysectomized rats in this study. Of the four doses of chicken pituitaries, ranging up to as much as four pituitaries, only

TABLE 18

*Effect of protein, dl-methionine, l-lysine and safflower oil on egg weight*

ARSCOTT and BERNIER (1970)

*Effet des protéines, dl-méthionine, l-lysine et huile de carthame sur le poids des œufs*

ARSCOTT et BERNIER (1970)

Prot., amino acid and/or SO (%)	Egg wt. (g)	
	Exp't 1	Exp't 2
<i>Dwarf</i>		
15.2 .....	51.7 <sup>a</sup> *	53.6 <sup>a</sup>
15.2 + .025 met. ....		53.9 <sup>ab</sup>
15.2 + .05 met. ....	54.1 <sup>b</sup>	54.6 <sup>ab</sup>
15.2 + .1 met. ....		55.6 <sup>bc</sup>
15.2 + .05 lys. ....	53.0 <sup>ab</sup>	
15.2 + 2 SO .....	53.3 <sup>ab</sup>	
15.2 + .05 met. + .05 lys. ....		54.7 <sup>abc</sup>
15.2 + .05 met. + 2 SO .....		55.5 <sup>bc</sup>
15.2 + .05 met. + .05 lys. + 2 SO .....		54.9 <sup>bc</sup>
20.9 .....	54.6 <sup>b</sup>	54.9 <sup>bc</sup>
<i>Normal</i>		
15.8 .....	56.1 <sup>c</sup>	57.2 <sup>d</sup>

\* Treatments with different letters are significantly different ( $P < .05$ ).

the highest dose originating from the normal chickens of both ages and from the older dwarfs brought about a significant weight response in the thyroids of hypophysectomized rats. Either the sensitivity of the rat thyroid to chicken thyrotropic stimulating hormone is low or the pituitary thyrotropic stimulating hormone is at a relatively low level in the chicken.

On the basis of pituitary cytological studies with sex-linked recessive dwarfism, van TIENHOVEN *et al.* (1966) have proposed that sex-linked recessive dwarfism is the result of a failure in the release of somatotropic hormone from the pituitary. They found that the anterior pituitaries of dwarf chickens showed frequent recurrence of small cells with secretory droplets which they speculated to be the result of an accumulation of somatotropic hormone because of a failure of its release into circulation. The pituitary bioassay results in our study do not support the contention of such an accumulation of somatotropic hormone. Total pituitary STH content of dwarfs did not differ significantly from that of normals at either age studied. Nevertheless it is still possible that a decreased pituitary secretion of STH which would not neces-

sarily be detected by a bioassay of only the pituitary glands could be a factor in dwarfism.

The possibility that ACTH and the adrenals may be involved in sex-linked recessive dwarfism must not be overlooked. The significant involvement of adrenal hor-

TABLE 19

*Effect of protein, dl-methionine, l-lysine  
and safflower oil on feed per dozen eggs*

ARSCOTT and BERNIER (1970)

*Effet des protéines, dl-méthionine, l-lysine et huile de carthame  
sur la consommation alimentaire par douzaine d'œufs*

ARSCOTT et BERNIER (1970)

Prot., amino acid and/or SO (%)	Feed per dozen eggs (lb)	
	Exp't 1	Exp't 2
<i>Dwarf</i>		
15.2 .....	3.97 <sup>a</sup> *	3.74 <sup>a</sup>
15.2 + .025 met. ....		3.71 <sup>ab</sup>
15.2 + .05 met. ....	3.65 <sup>a</sup>	3.53 <sup>bc</sup>
15.2 + .1 met. ....		3.65 <sup>abc</sup>
15.2 + .05 lys. ....	3.84 <sup>a</sup>	
15.2 + 2 SO .....	3.81 <sup>a</sup>	
15.2 + .05 met. + .05 lys. ....		3.69 <sup>abc</sup>
15.2 + .05 met. + 2 SO .....		3.74 <sup>a</sup>
15.2 + .05 met. + .05 lys. + 2 SO .....		3.61 <sup>abc</sup>
20.9 .....	3.58 <sup>a</sup>	3.66 <sup>abc</sup>
<i>Normal</i>		
15.8 .....	4.54 <sup>b</sup>	4.45 <sup>d</sup>

\* Treatments with different letters are significantly different ( $P < .05$ ).

mones in pathways of carbohydrate, protein, and fat metabolism in mammalian species is well known and the same general conclusion is probably also valid for birds.

As compared to the normals, the pituitary ACTH activity of dwarfs was lower at 2-3 months of age but comparable at 7-13 months of age. Incidentally pituitary ACTH concentration for both types of birds appeared to be higher at the younger age than at the older one, as did STH concentration which may well be a reflection of involvement at a time when growth is rapid. The absolute adrenal weight was significantly less in the dwarfs than in the normals at the younger age but not at the older one. The difference at the younger age was removed by expressing the weight of the adrenals relative to both absolute and metabolic body weight. The older dwarfs had larger adrenals than older normals relative to absolute body size but not to metabolic body size. This difference may be the result of stresses associated with different nutritional requirements of the two types of birds, particularly protein as demonstrated in our nutrition studies.

TABLE 20  
 Means and standard errors of means of body (absolute and metabolic) and of endocrine weights (absolute and relative to absolute and to metabolic) in dwarf and normal White Leghorn females  
 Moyennes et écarts-types des poids corporels moyens (absolus et métaboliques) et des poids de glandes endocrines (absolus ou rapportés au poids absolu et au poids métabolique) chez des femelles Leghorn blanches naines et normales

Type of chicken	Number of chickens	Age in mos	Body Weight		Hypophyseal Weight		
			Absolute (g)	Metabolic (W. <sup>(1)</sup> ) (g)	Absolute (mg)	Relative to body size	
Dwarf	21	2-3	716 ± 26.5 <sup>aa</sup> (1)	138.1 ± 3.9 <sup>a</sup>	4.2 ± 0.2 <sup>aa</sup> (19) (1)	0.60 ± 0.03 <sup>ab</sup>	3.08 ± 0.2 <sup>a</sup>
Normal	19	2-3	970 ± 34.1 <sup>bb</sup>	173.5 ± 4.6 <sup>b</sup>	5.9 ± 0.3 <sup>b</sup>	0.62 ± 0.03 <sup>ab</sup>	3.43 ± 0.2 <sup>ab</sup>
Dwarf	20	7-13	1147 ± 49.8 <sup>cc</sup>	196.4 ± 6.5 <sup>c</sup>	7.0 ± 0.4 <sup>cc</sup> (19)	0.65 ± 0.05 <sup>a</sup>	3.73 ± 0.2 <sup>b</sup>
Normal	20	7-13	1582 ± 33.2 <sup>da</sup>	250.6 ± 4.0 <sup>d</sup>	8.4 ± 0.6 <sup>cc</sup> (19)	0.53 ± 0.04 <sup>b</sup>	3.33 ± 0.2 <sup>ab</sup>
					Adrenal Weight		
			Relative to body size		Relative to body size		
			Absolute	Metabolic	Absolute	Metabolic	
			(mg/100 g)		(mg/100 g)		
Dwarf	61.7 ± 3.2 <sup>aa</sup>	8.8 ± 0.5 <sup>a</sup>	45.1 ± 2.5 <sup>a</sup>	176 ± 8.9 <sup>(16)</sup>	24.3 ± 1.2 <sup>a</sup>	1.26 ± 0.06 <sup>a</sup>	
Normal	79.7 ± 3.9 <sup>bb</sup>	8.3 ± 0.4 <sup>a</sup>	46.0 ± 2.0 <sup>a</sup>	295 ± 18.1 <sup>(19)</sup>	29.5 ± 1.5 <sup>b</sup>	1.65 ± 0.09 <sup>b</sup>	
Dwarf	121.1 ± 8.3 <sup>cc</sup> (17)	10.9 ± 0.7 <sup>b</sup>	62.7 ± 3.7 <sup>b</sup>	—	—	—	
Normal	135.9 ± 5.6 <sup>cc</sup> (18)	8.6 ± 0.4 <sup>a</sup>	54.4 ± 2.3 <sup>b</sup>	—	—	—	

(1) Means with different superscripts are significantly different at the 0.05 level of probability and at the .01 level when the letter is repeated.

(2) Number between ( ) represents the number of chickens in the sample when different from the number in the second column.

TABLE 21

Means and standard errors of means of comb weight and area, shank length (absolute and relative to absolute and to metabolic body weight) and carcass specific gravity of dwarf and normal White Leghorn females

Moyennes et écarts-types des poids et surfaces moyennes des crêtes, longueurs de tarses, longueurs de femelles Leghorn blanches au poids corporel absolu et métabolique) et poids spécifique des carcasses de femelles Leghorn blanches naines et normales

Type of chicken	Number of chickens	Age in mos	Comb Weight			Area (L × H)				
			Absolute (mg)	Relative to body weight		Absolute	Relative to body weight			
				Absolute (mg/100 g)	Absolute		Metabolic	Absolute	Metabolic	
Dwarf ...	21	2-3	0.36 ± 0.04 <sup>a(1)</sup>	0.049 ± 0.005 <sup>a</sup>	0.25 ± 0.02 <sup>a</sup>	3.5 ± 0.25 <sup>a</sup>	0.49 ± 0.04 <sup>a</sup>	2.50 ± 0.15 <sup>a</sup>		
Normal ..	19	2-3	0.57 ± 0.07 <sup>b</sup>	0.057 ± 0.006 <sup>a</sup>	0.32 ± 0.02 <sup>a</sup>	4.9 ± 0.40 <sup>b</sup>	0.50 ± 0.03 <sup>a</sup>	2.79 ± 0.19 <sup>a</sup>		
Dwarf ...	20	7-13	7.5 ± 0.90 <sup>c</sup>	0.658 ± 0.077 <sup>b</sup>	3.81 ± 0.45 <sup>b</sup>	28.4 ± 2.47 <sup>c</sup>	2.51 ± 0.21 <sup>b</sup>	14.52 ± 1.20 <sup>b</sup>		
Normal ..	20	7-13	11.6 ± 0.87 <sup>d</sup>	0.745 ± 0.060 <sup>b</sup>	4.68 ± 0.36 <sup>b</sup>	38.0 ± 1.98 <sup>d</sup>	2.42 ± 0.13 <sup>b</sup>	15.25 ± 0.28 <sup>b</sup>		
			Shank length						Carcass specific gravity	
			Absolute (cm)	Relative to body weight						
				Absolute	Metabolic	(cm/100 g)				
Dwarf .....			7.8 ± 0.07 <sup>a</sup>	1.12 ± 0.04 <sup>a</sup>	5.74 ± 0.14 <sup>a</sup>		1.040 <sup>a(10)</sup>			
Normal .....			9.5 ± 0.09 <sup>b(18)</sup>	1.00 ± 0.03 <sup>b</sup>	5.53 ± 0.11 <sup>a</sup>		1.040 <sup>a(10)</sup>			
Dwarf .....			7.9 ± 0.12 <sup>a(10)</sup>	0.68 ± 0.04 <sup>c</sup>	3.99 ± 0.15 <sup>b</sup>		1.045 <sup>a(10)</sup>			
Normal .....			9.4 ± 0.12 <sup>b(10)</sup>	0.62 ± 0.02 <sup>c</sup>	3.89 ± 0.10 <sup>b</sup>		1.041 <sup>a(11)</sup>			

(<sup>1</sup>) Means with different superscripts are significantly different at the 0.05 level of probability.

(<sup>2</sup>) Number between ( ) represents the number of chickens in the sample when different from the number in the second column.

TABLE 22  
*Means and standard errors of means of the thyroid and its histological characteristics (absolute and relative to absolute and to metabolic body weight) in dwarf and normal White Leghorn females*  
*Moyennes et écarts-types des poids moyens de la thyroïde et de ses caractéristiques histologiques (absolus et rapportés au poids corporel absolu et métabolique) chez des femelles Leghorn blanches naines et normales*

Type of chicken	Number of chickens	Age in mos	Thyroid					
			Absolute (mg)	Relative to body weight (mg/100 g)		Epithelial cell height (microns)	Colloid diameter (microns)	Follicle diameter (microns)
				Absolute	Metabolic			
Dwarf . . . .	21	2-3	49.9 ± 3.2 <sup>aa</sup> (1)	6.9 ± 0.3 <sup>a</sup>	35.8 ± 1.9 <sup>a</sup>	11.3 ± 0.3 <sup>a</sup>	76.5 ± 3.6 <sup>a</sup>	104.5 ± 3.7 <sup>a</sup>
Normal . . .	19	2-3	86.7 ± 7.9 <sup>bb</sup> (18)( <sup>2</sup> )	8.7 ± 0.6 <sup>bb</sup>	48.8 ± 3.5 <sup>b</sup>	11.9 ± 0.4 <sup>a</sup>	96.4 ± 4.3 <sup>b</sup>	130.5 ± 5.5 <sup>b</sup>
Dwarf . . . .	20	7-13	52.0 ± 6.3 <sup>aa</sup> (15)	4.5 ± 0.4 <sup>c</sup>	26.2 ± 2.4 <sup>c</sup>	7.7 ± 0.3 <sup>b</sup> (18)	75.0 ± 2.0 <sup>a</sup> (18)	98.7 ± 2.4 <sup>a</sup> (18)
Normal . . .	20	7-13	168.3 ± 11.9 <sup>cc</sup>	10.6 ± 0.7 <sup>d</sup>	66.8 ± 4.4 <sup>d</sup>	10.3 ± 0.8 <sup>a</sup> (18)	138.0 ± 12.4 <sup>c</sup> (12)	178.6 ± 15.2 <sup>c</sup> (12)

(<sup>1</sup>) Means with different superscripts are significantly different at the 0.05 level of probability and at the .01 level if the letter is repeated.

(<sup>2</sup>) Number between ( ) represents the number of chickens in the sample when different from the number in the second column.

TABLE 23

*Response in immature, hypophysectomized female rats to hypophysal homogenates from normal and dwarf White Leghorn females*  
*Réponse de ratte immatures hypophysectomisées à des homogénats hypophysaires de femelles Leghorn blanches normales et naines*

Type of chicken	Age of chickens mos	No of rats	Total dose (1)	Body weight gain (g)	Epiphysal width (microns)	Tail length (cm)	Adrenal weight (mg)	Thymus weight (mg)
Dwarf	2-3	2	4	12.0 ± 2.0 <sup>aa</sup> (3)	270 ± 0.5 <sup>bb</sup>	11.3 ± 0.8 <sup>b</sup>	13.5 ± 2.1 <sup>a</sup> (5)	286 ± 88.5 <sup>b</sup>
		3	2	7.0 ± 0.6 <sup>aa</sup>	222 ± 38.4 <sup>a</sup>	11.5 ± 0.3 <sup>b</sup>	10.2 ± — <sup>a</sup> (5)	303 ± 29.9 <sup>a</sup>
		3	1	6.3 ± 1.2 <sup>a</sup>	225 ± 31.0 <sup>b</sup>	12.3 ± 0.4 <sup>b</sup>	10.5 ± 0.5 <sup>a</sup> (5)	284 ± 33.7 <sup>b</sup>
Normal	2-3	3	1/4	3.3 ± 1.2 <sup>b</sup>	181 ± 3.1 <sup>bb</sup>	11.8 ± 0.2 <sup>b</sup>	9.5 ± 0.6 <sup>b</sup> (5)	223 ± 18.2 <sup>b</sup>
		2	4	8.5 ± 0.5 <sup>aa</sup>	270 ± 65.0 <sup>a</sup>	13.7 ± 0.8 <sup>a</sup>	18.4 ± 1.0 <sup>aa</sup>	314 ± 28.1 <sup>a</sup>
		2	2	5.5 ± 0.5 <sup>a</sup>	221 ± 36.0 <sup>a</sup>	11.4 ± 0.1 <sup>b</sup>	12.3 ± 1.3 <sup>a</sup>	236 ± 25.6 <sup>b</sup>
Dwarf	7-13	3	1	6.3 ± 0.9 <sup>a</sup>	210 ± 24.9 <sup>b</sup>	11.7 ± 0.2 <sup>b</sup>	10.6 ± 2.1 <sup>b</sup>	273 ± 30.2 <sup>b</sup>
		3	1/4	4.0 ± 2.5 <sup>b</sup>	219 ± 56.2 <sup>a</sup>	12.1 ± 0.5 <sup>b</sup>	15.3 ± 6.0 <sup>b</sup>	261 ± 69.5 <sup>b</sup>
		2	4	9.5 ± 1.5 <sup>aa</sup>	203 ± 13.0 <sup>bb</sup>	12.4 ± 0.1 <sup>aa</sup>	8.8 ± 0.4 <sup>b</sup>	307 ± 4.8 <sup>aa</sup>
Normal	7-13	3	2	8.3 ± 0.3 <sup>aa</sup>	179 ± 26.0	11.9 ± 0.4 <sup>b</sup>	8.7 ± 0.8 <sup>b</sup>	233 ± 40.2 <sup>b</sup>
		3	1	8.3 ± 1.3 <sup>aa</sup>	239 ± 6.2 <sup>bb</sup>	11.5 ± 0.3 <sup>b</sup>	8.9 ± 1.3 <sup>b</sup>	224 ± 25.8 <sup>b</sup>
		3	1/4	5.3 ± 0.3 <sup>a</sup>	183 ± 9.3 <sup>bb</sup>	11.4 ± 0.3 <sup>b</sup>	7.6 ± 1.2 <sup>b</sup>	159 ± 13.8 <sup>a</sup>
Saline-injected control rats	control	2	4	10.0 ± 2.0 <sup>aa</sup>	209 ± 2.5 <sup>bb</sup>	12.6 ± 0.1 <sup>aa</sup>	9.1 ± 0.9 <sup>b</sup>	259 ± 19.7 <sup>b</sup>
		3	2	8.0 ± 1.7 <sup>a</sup>	192 ± 23.5 <sup>a</sup>	11.5 ± 0.7 <sup>b</sup>	12.0 ± 0.1 <sup>aa</sup>	273 ± 30.9 <sup>b</sup>
		3	1	7.0 ± 1.2 <sup>a</sup>	191 ± 3.7 <sup>bb</sup>	12.0 ± 0.2	9.9 ± 1.2 <sup>b</sup>	300 ± 7.0 <sup>aa</sup>
		3	1/4	2.4 ± 1.2 <sup>b</sup>	174 ± 5.0 <sup>bb</sup>	11.9 ± 0.4 <sup>b</sup>	9.4 ± 0.6	222 ± 52.9 <sup>b</sup>
		13	0	2.5 ± 1.1 <sup>b</sup> (2)	147 ± 6.8 <sup>a</sup> (2)	11.6 ± 0.1 <sup>b</sup>	8.7 ± 0.5 <sup>b</sup> (4)	217 ± 17.8 <sup>b</sup>

(1) Refers to total number of pituitaries administered per rat over the 4-day treatment period.

(2) Means with a superscript different from that of the control mean are significantly different at the .05 level of probability and at the .01 level if the letter is repeated.

(3) Treated rats as a group significantly different from the control rats at P < .01.

(4) Treated rats as a group significantly different from control rats at P < .05.

(5) Rats treated with pituitaries from dwarf chickens at 2-3 mos. of age significantly different at P < .05 from rats treated with pituitaries from normal chickens at 2-3 mos. of age and from control rats.

TABLE 24

*Gonadotropic responses of immature, hypophysectomized female rats to hypophyseal homogenates from normal and dwarf White Leghorn females*  
*Réponses gonadotropes de rattes immatures hypophysectomisées à des homogénats hypophysaires de femelles Leghorn blanches normales et naines*

Type of chicken	Age of chickens mos	Number of rats	Total dose (1)	Ovarian weight (mg)	Oviduct and uterus weight (mg)	Ovarian follicle diameter (microns)	Ovarian interstitial cell response (2)	
							(+)	(-)
Dwarf	2-3	2	4	9.4 ± — <sup>bb</sup> (4)	22.1 ± 1.9 <sup>b</sup>	468 ± 31.2 <sup>a</sup>	2	0
		3	2	7.2 ± 0.8 <sup>a</sup>	19.6 ± 1.3 <sup>b</sup>	381 ± 17.3 <sup>b</sup>	3	0
		3	1	6.3 ± 1.0 <sup>a</sup>	21.6 ± 1.9 <sup>b</sup>	395 ± 21.6 <sup>b</sup>	3	0
		3	1/4	6.7 ± 1.0 <sup>a</sup>	17.9 ± 1.5 <sup>b</sup>	367 ± 25.0 <sup>b</sup>	0	3
Normal	2-3	2	4	7.5 ± 2.9 <sup>a</sup>	29.6 ± 2.0 <sup>aa</sup>	432 ± 5.2 <sup>aa</sup>	2	0
		2	2	10.5 ± 2.9 <sup>a</sup>	23.4 ± 4.2 <sup>b</sup>	421 ± 5.2 <sup>aa</sup>	2	0
		3	1	9.9 ± 1.9 <sup>a</sup>	21.3 ± 3.1 <sup>b</sup>	423 ± 24.3 <sup>bb</sup>	2	1
		3	1/4	6.5 ± 0.3 <sup>a</sup>	20.7 ± 4.5 <sup>b</sup>	406 ± 21.6 <sup>b</sup>	1	2
Dwarf	7-13	2	4	14.6 ± 1.6 <sup>bb</sup>	62.5 ± 1.9 <sup>aa</sup>	390 ± 26.0 <sup>b</sup>	2	0
		3	2	10.5 ± 1.3 <sup>a</sup>	36.7 ± 6.4 <sup>a</sup>	402 ± 33.1 <sup>b</sup>	3	0
		3	1	10.7 ± 0.7 <sup>bb</sup>	24.1 ± 2.7 <sup>b</sup>	361 ± 9.2 <sup>b</sup>	2	1
		3	1/4	7.7 ± 0.7 <sup>a</sup>	20.2 ± 0.3 <sup>a</sup>	343 ± 26.2 <sup>b</sup>	1	2
Normal	7-13	2	4	11.2 ± 0.2 <sup>bb</sup>	55.1 ± 3.1 <sup>aa</sup>	390 ± 15.6 <sup>b</sup>	2	0
		3	2	10.5 ± 0.3 <sup>bb</sup>	36.0 ± 8.5 <sup>b</sup>	392 ± 29.6 <sup>b</sup>	3	0
		3	1	9.1 ± 0.9 <sup>a</sup>	23.7 ± 3.4 <sup>b</sup>	374 ± 21.6 <sup>b</sup>	0	3
		3	1/4	8.6 ± 0.5 <sup>a</sup>	22.3 ± 1.2 <sup>a</sup>	361 ± 30.2 <sup>b</sup>	0	3
Saline-injected control rats ...		13	0	7.7 ± 0.5 <sup>a</sup> (3)	18.2 ± 0.7 <sup>b</sup> (3)	371 ± 10.4 <sup>b</sup>	0	13

(1) Refers to total number of pituitaries administered per rat over the 4-day period.

(2) Number of rats showing a positive (+) or negative (-) ovarian interstitial cell response.

(3) All treated rats significantly different at  $P < .01$  from saline-injected rats.

(4) Means with a superscript different from that of the control mean are significantly different at the .05 level of probability and at the .01 level if the letter is repeated.

TABLE 25

*Characteristics of the thyroid in the assay rats in response to hypophyseal homogenates from normal and dwarf White Leghorn females*  
*Caractéristiques de la thyroïde de rats-tests en réponse à des homogénats hypophysaires de femelles Leghorn blanches normales et naines*

Type of chicken	Age of chickens mos	N <sup>o</sup> of rats	Total dose (†)	Absolute weight (mg)	Epithelial cell height (microns)	Colloid diameter (microns)	Follicle diameter (microns)
Dwarf	2-3	2	4	4.3 ± 0.9 <sup>b</sup> (2)	8.4 ± 0.6 <sup>a</sup>	48.3 ± 3.6 <sup>a</sup>	75.0 ± 3.0 <sup>a</sup>
		3	2	4.5 ± 1.0 <sup>b</sup>	6.2 ± 0.4 <sup>b</sup>	48.3 ± 3.1 <sup>a</sup>	69.2 ± 3.2 <sup>a</sup>
		3	1	6.3 ± 0.1 <sup>a</sup>	6.6 ± 0.4 <sup>b</sup>	57.8 ± 5.2 <sup>a</sup>	79.2 ± 6.0 <sup>a</sup>
		3	1/4	4.8 ± 0.7 <sup>b</sup>	6.8 ± 0.3 <sup>b</sup>	52.9 ± 3.4 <sup>a</sup>	74.2 ± 2.7 <sup>a</sup>
Normal	2-3	2	4	7.0 ± 0.4 <sup>aa</sup>	8.0 ± 0.5 <sup>a</sup>	50.5 ± 3.7 <sup>a</sup>	73.6 ± 4.6 <sup>a</sup>
		2	2	4.0 ± 0.0 <sup>aa</sup>	7.9 ± 0.4 <sup>a</sup>	51.1 ± 4.2 <sup>a</sup>	73.2 ± 4.4 <sup>a</sup>
		3	1	6.0 ± 1.4 <sup>b</sup>	7.5 ± 0.4 <sup>b</sup>	49.8 ± 3.6 <sup>a</sup>	74.7 ± 4.0 <sup>a</sup>
		3	1/4	5.9 ± 2.3 <sup>b</sup>	6.9 ± 0.4 <sup>b</sup>	51.6 ± 5.1 <sup>a</sup>	73.0 ± 5.5 <sup>a</sup>
Dwarf	7-13	2	4	6.8 ± 0.0 <sup>aa</sup>	7.2 ± 0.3 <sup>b</sup>	51.8 ± 3.2 <sup>a</sup>	73.8 ± 3.8 <sup>a</sup>
		3	2	6.6 ± 0.1 <sup>aa</sup>	7.8 ± 0.3 <sup>aa</sup>	53.2 ± 4.9 <sup>a</sup>	83.0 ± 5.3 <sup>a</sup>
		3	1	6.5 ± 0.5 <sup>b</sup>	6.5 ± 0.2 <sup>b</sup>	49.2 ± 2.9 <sup>a</sup>	63.9 ± 3.1 <sup>bb</sup>
		3	1/4	4.9 ± 0.5 <sup>b</sup>	6.0 ± 0.3 <sup>aa</sup>	50.8 ± 2.6 <sup>a</sup>	67.7 ± 3.1 <sup>a</sup>
Normal	7-13	2	4	7.8 ± 0.4 <sup>aa</sup>	7.5 ± 0.4 <sup>b</sup>	44.9 ± 4.3 <sup>a</sup>	66.2 ± 4.5 <sup>a</sup>
		3	2	6.8 ± 1.8 <sup>b</sup>	7.5 ± 0.3 <sup>b</sup>	53.1 ± 2.9 <sup>b</sup>	78.6 ± 3.7 <sup>a</sup>
		3	1	5.1 ± 1.2 <sup>b</sup>	8.2 ± 0.4 <sup>aa</sup>	51.4 ± 3.4 <sup>a</sup>	76.6 ± 2.8 <sup>a</sup>
		3	1/4	4.7 ± 0.4 <sup>b</sup>	6.8 ± 0.3 <sup>b</sup>	52.9 ± 3.2 <sup>a</sup>	71.9 ± 3.2 <sup>a</sup>
Saline-injected control rats.		13	0	5.6 ± 0.2 <sup>b</sup>	6.9 ± 0.2 <sup>b</sup>	52.9 ± 1.9 <sup>a</sup>	73.6 ± 2.1 <sup>a</sup>

(†) Refers to total number of pituitaries administered per rat over the 4-day period.

(<sup>a</sup>) Means with a different superscript from that of the control mean are significantly different at the .05 level of probability and at the .01 level if the letter is repeated.

Gonadotropin content of the hypophyses of dwarf and normal chickens appeared comparable at both ages as evidenced by ovarian and uterine weight responses together with ovarian histological responses in the assay rats. There were no apparent differences in ovarian weight and in comb weight and area, comb size being an indirect reflection of ICSH activity. It is also of interest to note that van TIENHOVEN *et al.* (1966) were unable to find differences in the presumptive gonadotropic cells between the two types of chickens upon histological examination.

It would appear from the result of this study that sex-linked dwarfism may possibly involve more than one endocrine disturbance, possibly other endocrine structures not considered in the present study such as the pancreas. The development of procedures, such as radioimmunoassay, that allow detection of circulating levels of hormones from the pituitary will greatly facilitate progress in solving the problem.

Hormone administration, as has been done with thyroidal principles (van TIENHOVEN *et al.*, 1966; BERNIER, 1965, unpublished) would appear to be a promising approach to study the endocrine basis of dwarfism. Because of the species specificity problem existing for protein hormones, it would be advisable to obtain such hormonal materials from chickens for experimental purposes. Unfortunately these materials are not, to our knowledge, readily available at the present time.

So much then for the evidence we have accumulated on the economic potential of dwarfism in egg production. Another area of great promise is that of management, more particularly housing density, or to paraphrase H. B. WALLACE (1970), oviduct density per square foot. We have not worked in that area but we were pleased to note a significant study by NORDSKOG & BRIGGS (1968) which needs to be placed in its proper perspective to be fully appreciated. Before the advent of the broiler industry the profitability of an egg enterprise depended not on egg production but also on the salvage value of body weight which meant reduced depreciation. There was also a general belief amongst poultrymen that body size was indicative of stamina because larger birds appeared to stand up better under conditions of stress. The evidence as reviewed by HUTT (1949) appeared to show a curvilinear relation between body weight and egg production although the extensive data of TAYLOR (1930) collected in Canada supported a linear relation in *Leghorns*.

In the light of the popular belief and the experimental evidence relating heavier egg production in heavier *Leghorns*, the recent study of NORDSKOG and BRIGGS (1968) elucidates the body-weight paradox as they termed it. They found that heavier birds stand up better under environmental stress but that smaller birds are genetically superior in egg production. There is thus an antagonism between the genetical and the environmental effects. In itself this antagonism justifies the trend to controlled environmental housing for egg production. We have noted in our work that minilayers withstand short periods of hot weather better than our normal size layers while the reverse is true in periods of cold weather.

We remain optimistic on the future of the minilayer for commercial egg production and we hope it eventually fulfills our great expectations.

## RÉSUMÉ

QUINZE ANS D'OBSERVATIONS SUR LE GÈNE DE NANISME  
CHEZ LA POULE DOMESTIQUE

Les observations sur le nanisme à la S. E. A. de l'Oregon remontent à 1952, mais l'étude systématique n'a commencé qu'en 1956. Des mutants nains ont été observés chez des *Cornish* et dans deux lignées consanguines de *Leghorn* et ont aussi été obtenus d'un accoureur local.

Une femelle mosaïque pour le nanisme et la taille normale a été observée dans la descendance de mâles nains accouplés à des femelles de taille normale. Cette femelle est génétiquement naine, toute la descendance l'étant. Un éperon s'est développé sur le tarse le plus grand. On suppose que le globule polaire contenant le chromosome sexuel porteur du gène pour la taille normale s'est réuni à l'une des deux cellules issues du premier élvage. Ceci a eu pour résultat une demi-femelle naine et un demi « neutre » triploïde de taille normale. L'analyse cytologique du sang et des follicules de plumes n'a pas révélé d'anomalie du caryotype.

Un létal récessif lié au sexe a été observé chez un mâle nain ayant une production de sperme exceptionnellement élevée. La moitié des embryons femelles issus du mâle porteur meurent très précocement et sont souvent classés comme infertiles. Des mâles nains accouplés à des femelles normales seraient un moyen commun d'obtenir des pondeuses naines, mais la disparité de taille pourrait éventuellement réduire le taux de fertilité dans les accouplements naturels.

Une proportion des mâles aux femelles de 1 à 15 et de 1 à 10 a donné jusqu'à cette année environ 80 p. 100 de fertilité. Une période d'au moins trois ou quatre semaines est apparue nécessaire pour atteindre ce niveau de fertilité, quoique celle-ci ait continué à augmenter lentement pendant 30-35 jours. Dans la période 1966-1971, les mâles ont été transférés directement de locaux sombres à des parquets éclairés avec les femelles. Cette année, les mâles étaient d'abord exposés à quinze heures de lumière pendant un mois avant d'être placés avec les femelles. La fertilité a augmenté beaucoup plus vite, atteignant 90 p. 100 en 15 jours, 95 p. 100 en 21 jours, mais la proportion était encore 1 mâle/10 femelles.

Les naines de lignée pure gardées en cages individuelles et reproduites par insémination artificielle ont montré une fertilité et un taux d'éclosion comparables à celles obtenues avec les femelles de taille normale.

Dans notre sélection génétique pour la production d'œufs des poules mises en poulaillers sur la base des performances individuelles et familiales, les résultats ont été pendant un certain temps décevants. Ceci provient apparemment de ce que des polygènes pour l'hypothyroïdisme étaient en ségrégation par suite de la consanguinité qu'accompagnait notre sélection. L'âge au premier œuf a augmenté jusqu'à la valeur de 32,5 semaines, mais il a ensuite décliné graduellement jusqu'à 24,3 semaines à la génération actuelle, ce qui représente encore une maturité de 1,7 semaines plus tardive que dans notre lignée de production *OSU*.

La production des poules mises en poulailler a été assez décevante pendant un certain nombre d'années, mais elle a commencé à s'améliorer dans les trois dernières générations. Elle représente maintenant 83,4 p. 100 de celle observée dans la lignée « Production » à 40 semaines d'âge. La taille des œufs a augmenté graduellement. Le poids corporel n'a pas changé à cause de la restriction à laquelle il était soumis dans notre sélection. Sinon, il aurait très vraisemblablement changé, comme réponse liée à notre sélection pour la taille des œufs.

Des études de nutrition ont été conduites avec des populations d'effectif allant de 240 animaux les premières années à plus de 1 200 pondeuses naines dans les années plus récentes, par groupes de 60. Nous avons mis en évidence le fait que les poulettes naines, même compte tenu de leur maturité sexuelle retardée, ont besoin d'une quantité d'aliments plus faible pour atteindre l'âge de la ponte. Les études de nutrition ont porté sur l'influence :

1. Des taux de calcium.
2. Du doublement du taux normal de vitamines et d'oligoéléments.
3. Du taux protéique jusqu'à 21 p. 100.
4. De la supplémentation en méthionine lysine et acide linséique.

Quoique la production d'œufs ait plafonné à partir du taux protéique de 15 p. 100, la taille des œufs a continué à augmenter jusqu'à 21 p. 100. L'addition de 0,05 p. 100 de méthionine a augmenté la ponte et le poids des œufs significativement et à des niveaux comparables à ceux observés avec une ration à 21 p. 100 de protéines. Actuellement, un faible taux de protamine est donné aux pondeuses élevées avec ou sans supplément de protamine, mais ce taux a dû être réduit de moitié, jusqu'à 0,0167 p. 100, car il abaissait la ponte.

Les études physiologiques ont inclus l'observation des hypophyses, thyroïdes, surrénales et ovaires, à la fois pour des femelles en croissance et adultes, ainsi qu'un test biologique d'homogénéats hypophysaires sur des rates immatures hypophysectomisées. Quoique les thyroïdes des femelles naines soient apparues plus petites que celles des normales à 7-13 mois d'âge, le test biologique n'a pu prouver que les modifications thyroïdiennes chez les naines soient dues à des altérations de l'activité thyrotrope de leur hypophyse.

Le résultat du test biologique des hypophyses ne confirme pas l'hypothèse de l'accumulation d'hormone somatotrope dans les hypophyses d'oiseaux nains. L'observation de l'ACTH et de l'activité gonadotrope a été faite aussi sur les hypophyses de naines.

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