THE ENDOCRINE SYSTEM AND PLUMAGE TYPES

III. FURTHER EXPERIMENTS ON THE RELATION BETWEEN THE THYROID GLAND AND PLUMAGE PATTERNS IN DOMESTIC FOWLS AND DUCKS

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INTRODUCTION

Some controversy is revealed in the studies of previous workers with regard to the effect of hyperthyroidism on the modification of plumage pattern in domestic fowls. Early experiments showed that female plumage can be successfully induced in some breeds of fowls simply by feeding fresh or desiccated thyroid glands to the male and it was therefore concluded that the production of female plumage is dependent upon a condition of relative hyperthyroidism in the female (Torrey & Horning, 1922, 1923; Cole & Reid, 1924; Horning & Torrey, 1927; Hutt, 1927; Cole & Hutt, 1928; and others). However, Greenwood & Blyth (1929) were unable to confirm these results in the Brown Leghorn and Chu (1938) related the feather patterns produced by thyroid gland medication in males of this breed to the intermediate types of plumage displayed in the juvenile chicks. The existing discrepancy is undoubtedly due to the use of different breeds of fowls by different authors.

There is a suggestion that at least four groups of fowls manifest divergent plumage reactions under the influence of hyperthyroidism. Group A (Brown Leghorn type): In this group of birds both colour and structure of the feather show an extreme degree of sex dimorphism. The males react to the thyroid substance with increase in the amount of melanin and of barbule formation, but without any indication of approximation to the female pattern. Group B (Silver Wyandotte type): The plumage characters of this breed are similar to those of Brown Leghorns in showing extreme sex dimorphism, but the males under the influence of hyperthyroidism will assume a plumage characteristic of the female. Group C (Rhode Island Red type): The plumage is non- or self-coloured and differs only in structure in the two sexes. Thyroid administration brings about the assumption of female plumage in the males. Group D (Sebright bantam type): The plumage is the same in the two sexes and resembles that of the hen in the sexually dimorphic breeds. Thyroid
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gland feeding to the male has been said to result in no change of feather pattern.

With regard to the effect of extirpation of the thyroid gland, Greenwood & Blyth (1929) showed, in Brown Leghorns, that the phenomena exhibited were the reverse of those obtained through hyperthyroidism in the male, i.e. a decrease in melanin and barbule formation. The same changes occurred in the female, though to a lesser degree, following ablation of the thyroid gland. These results have been confirmed by Parkes & Selye (1937) and by Chu (1938). The former authors carried out the operation on several breeds of fowls and found that either colour or structural alteration of the feather always followed thyroid extirpation. It is the purpose of this study to extend the experiments on hypo- and hyperthyroidism to some other breeds with or without sex dimorphic plumage in order to elucidate the role of this endocrine gland in the expression of different feather types and to group them in an appropriate order as mentioned above based on the nature of plumage reactions under experimental conditions.

Technique and Results

The technique of thyroidectomy is essentially the same as that described in a previous communication (Chu, 1936). All the birds operated upon were under deep anaesthesia. Ether was used for the bantams and pigeons, but for some large fowls (such as Rocks and ducks), nembutal was given by injection into a wing vein. In the thyroid-fed group, desiccated thyroid gland (B.D.H.) was administered daily, the doses varying according to the size of the birds. The birds used were game bantams (duckwing and partridge), fowls (Barred, Silver-black, and White Rocks), ducks (mallard), and pigeons (racing) from the farm stocks of the Institute. At the beginning of an experiment regions of the body such as breast, wing bow, shoulder, cape, back and saddle were denuded to obtain newly regenerated feathers.

Hypothyroidism

Retardation of growth of feathers in the denuded areas was a very pronounced effect of hypothyroidism. In a small number of birds the denuded areas failed to regenerate new feathers up to the end of experiments. Since the majority were thyroidectomized in September 1938, i.e. at the period when the annual moult is to be expected in the greater proportion of normal fowls, it is significant that not even a single cast feather was found in the cages of the operated birds. A male mallard,
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PC 72, thyroidectomized on 24 September 1938, was at the time of operation in the autumnal moult, the eclipse plumage being replaced by the nuptial. The moult, however, had not been completed, and the plumage of this bird was partially eclipse and partially nuptial. After the operation the bird failed to complete the moult and feathers of eclipse type were still to be found in some regions of the body up to May of this year. It has been demonstrated in birds (Zavadovsky, 1935) that administration of excessive thyroid substance or thyroxin results in

**TABLE I**

<table>
<thead>
<tr>
<th>Bird's no.</th>
<th>Breed</th>
<th>Sex</th>
<th>Date of operation</th>
<th>Date of death</th>
<th>Survival period</th>
<th>Feather changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC 54</td>
<td>Duckwing game bantam</td>
<td>♂</td>
<td>12. ix. 38</td>
<td>14. x. 38</td>
<td>22</td>
<td>Colour and structure</td>
</tr>
<tr>
<td>46</td>
<td></td>
<td>♂</td>
<td>14. ix. 38</td>
<td>11. xi. 38</td>
<td>58</td>
<td>Colour and structure</td>
</tr>
<tr>
<td>45</td>
<td></td>
<td></td>
<td>14. ix. 38</td>
<td>17. x. 38</td>
<td>33</td>
<td>Colour and structure</td>
</tr>
<tr>
<td>44</td>
<td></td>
<td>♀</td>
<td>15. ix. 38</td>
<td>18. xii. 38</td>
<td>94</td>
<td>Colour and structure</td>
</tr>
<tr>
<td>43</td>
<td>Partridge game bantam</td>
<td>♀</td>
<td>13. ix. 38</td>
<td>23. x. 38</td>
<td>42</td>
<td>Colour and structure</td>
</tr>
<tr>
<td>47</td>
<td></td>
<td></td>
<td>13. ix. 38</td>
<td>29. i. 39</td>
<td>137</td>
<td>Colour and structure</td>
</tr>
<tr>
<td>PC 66</td>
<td>Barred Rock</td>
<td>♂</td>
<td>8. ix. 38</td>
<td>20. xii. 38</td>
<td>103</td>
<td>Structure</td>
</tr>
<tr>
<td>65</td>
<td></td>
<td>♂</td>
<td>8. ix. 38</td>
<td>21. xi. 38</td>
<td>74</td>
<td>Structure</td>
</tr>
<tr>
<td>PC 63</td>
<td>White Rock</td>
<td>♂</td>
<td>8. ix. 38</td>
<td>8. x. 38</td>
<td>61</td>
<td>Structure</td>
</tr>
<tr>
<td>PC 57</td>
<td></td>
<td>♂</td>
<td>10. ix. 38</td>
<td>6. i. 38</td>
<td>117</td>
<td>Structure</td>
</tr>
<tr>
<td>PC 66</td>
<td></td>
<td>♀</td>
<td>10. ix. 38</td>
<td>22. i. 39</td>
<td>133</td>
<td>Structure</td>
</tr>
<tr>
<td>PC 60</td>
<td>Mallard</td>
<td>♂</td>
<td>14. ix. 38</td>
<td>—</td>
<td>—</td>
<td>No feather growth</td>
</tr>
<tr>
<td>59</td>
<td></td>
<td>♂</td>
<td>14. ix. 38</td>
<td>22. xii. 38</td>
<td>99</td>
<td>Colour and structure</td>
</tr>
<tr>
<td>PC 62</td>
<td></td>
<td>♀</td>
<td>24. iv. 38</td>
<td>—</td>
<td>—</td>
<td>No feather growth</td>
</tr>
<tr>
<td>40</td>
<td>Pigeon</td>
<td>♀</td>
<td>23. ix. 38</td>
<td>3. iv. 39</td>
<td>122</td>
<td>Structure</td>
</tr>
</tbody>
</table>

Heavy casting of feathers. After thyroidectomy the opposite phenomenon is encountered, even the normal process of moult being inhibited.

Although the ability to regenerate feathers was poor in thyroidectomized birds, adequate material was still available for the study of feather patterns produced under a condition of hypothyroidism.

**Duckwing game bantam.** The normal plumage of this breed is, roughly speaking, white with varying amount of black pigment. The structural and colour differences in the two sexes are just the same as those described for the Silver Dorking breed (see Parkes & Selyc, 1937). Three males and one female have been completely thyroidectomized.
The most marked changes of plumage observed in the males were the entire disappearance of melanin and the appearance of fringing in those feathers normally solid. The regional differences of colour pattern and of structure were no longer obvious in the thyroidectomized birds. Although the general tendency was to reduction in the number of barbules, those feathers having normally a compact texture remained with more barbules than those normally fringed. In the female the tendency to a decrease in melanin and barbule formation resulted in the complete obliteration of female characteristics, though some sporadic dark pigment was still observable in the solid core of the regenerated feathers. Obviously, in the absence of the thyroid gland, the feather pattern became a basic one, being common to both sexes regardless of the activity of the gonad.

*P. g. bantam.* The plumage of the female Partridge is different in ground colour from that of the female Duckwing and similar to that of Brown Leghorn hens. It is of a drab brownish colour with fine black stipplings, except on the breast, where the plumage is of a salmon hue. The operation caused intense changes both in feather colour and structure. The breast feathers did not alter in colour but they became fringed. Red pigment appeared in feathers of the saddle, back, cape, neck, and wing bow at the expense of black pigment. As a result of decrease in the number of barbules, feathers of different regions became heavily fringed, with the exception of the wing flights and tail feathers. The typical female stippling was much reduced or had disappeared altogether. The results obtained from these birds were the same as for the Brown Leghorn female (Greenwood & Blyth, 1929; Parkes & Salye, 1937; Greenwood & Chu, 1939).

**Barred Rock.** The normal feathering in this breed shows a barred pattern of greenish black and bluish white. The male plumage differs from the female merely in the fringing of certain dorsal feathers, so that sex dimorphism is structural only.

Two completely thyroidectomized males survived for 103 and 74 days respectively and provided material for a detailed study of regenerated feathers. Feathers grown in the denuded areas shortly after operation appeared quite normal in colour and size, but the number of barbules was greatly reduced, especially in the breast feathers, which were deeply fringed. Feathers obtained at a later stage showed a further degree of hypothyroidism in that, besides the deprivation of barbules, they were much shortened and slender with no differentiation of fluff. The black bars also were closer together than is normal.
White Rock. The plumage in both sexes is self-white. The only characteristic difference between the male and the female is in structure.

In the one male and two females studied, thyroidectomy led to the poor development of barbules, but the colour was unchanged and the different degrees of fringing exhibited in the various body regions of the female resulted in a male-like plumage.

Silver-black Rock. In this breed sexual dimorphism of the plumage is well marked: that of the male is a mixture of black and silver white, while the female is pure black. Structural differences are the same as other breeds.

On account of the poor vitality of the operated birds, only one female was kept a sufficiently long time for observation. As in the other varieties of Rocks, thyroidectomy resulted only in the reduction of barbules with no alteration in colour pattern.

Mallard. Regional differentiation is very marked in the nuptial plumage of the mallard drake. Ventrally the crop feathers are dark brown coloured. The keel and side keel show a hue of whitish grey stippled with dark pigment. On the dorsal surface, feathers on the cape are dark grey with fine light stipplings; this hue darkens from before backwards and becomes dull black on the back and sheen black on the rump. The head feathers have a metallic green sheen. The eclipse plumage assumed in the summer resembles that of the female, which is rich in black and brown pigment.

Three drakes in nuptial plumage were successfully thyroidectomized, but only one showed subsequent regeneration of feathers in the denuded areas. Reduction of barbules was marked, but not so much as in the fowl. The new feathers were mostly very slender and loose. Colour changes occurred only in feathers of the dorsal areas, which tended to change to the whitish stippled type characteristic of the posterior ventral feathers. This is a similar effect to that in the Khaki Campbell drake reported by Parkes & Selye (1937).

Pigeon. The plumage of the pigeon is not sex dimorphic and is independent of the gonads for its character. It is uniformly grey and metallic green on the head and the neck. No other regional differentiation of either colour or structure is evident in either sex. Structurally the feathers are solid with full development of barbules.

One thyroidectomized female showed significant structural changes in the regenerated feathers. This was the reduction of barbules, which made the feathers fluffy in appearance. No colour alteration was seen.
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Hyperthyroidism

All the experiments were carried out under the same conditions of husbandry as with the thyroidectomized birds, except for the daily administration of desiccated thyroid gland. The birds used, the dosage, the length of the feeding period and the resultant plumage changes are summarized in Table II.

Duckwing game bantam. Two adult duckwing males were subjected to treatment. The daily dosage was 150 mg. of desiccated thyroid substance. At the commencement of the experiment patches of feathers were plucked from the breast, wing bow, shoulder, back, saddle, cape, and neck, so that growing feathers in all the denuded areas developed under the influence of hyperthyroidism. One bird died on the 31st day of

TABLE II

<table>
<thead>
<tr>
<th>Bird's no.</th>
<th>Breed</th>
<th>Sex</th>
<th>Size of dosage (per day)</th>
<th>Date feeding started</th>
<th>Date feeding stopped</th>
<th>Feather changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>37</td>
<td>Duckwing bantam</td>
<td>♂</td>
<td>150</td>
<td>27. ix. 38</td>
<td>23. x. 38</td>
<td>Colour and structure</td>
</tr>
<tr>
<td>35</td>
<td>&quot;</td>
<td>♂</td>
<td>150</td>
<td>27. ix. 38</td>
<td>4. xi. 38</td>
<td>Colour and structure</td>
</tr>
<tr>
<td>PC 81</td>
<td>Barred Rock</td>
<td>♂</td>
<td>390</td>
<td>23. ix. 38</td>
<td>20. xii. 38</td>
<td>Structure</td>
</tr>
<tr>
<td>PC 82</td>
<td>&quot;</td>
<td>♂</td>
<td>390</td>
<td>23. ix. 38</td>
<td>20. xii. 38</td>
<td>Structure</td>
</tr>
<tr>
<td>PC 90</td>
<td>White Rock</td>
<td>♂</td>
<td>300</td>
<td>27. ix. 38</td>
<td>22. xii. 38</td>
<td>Colour</td>
</tr>
<tr>
<td>PC 77</td>
<td>Railroad</td>
<td>♂</td>
<td>300</td>
<td>(49 days)</td>
<td>22. xii. 38</td>
<td>Colour</td>
</tr>
<tr>
<td>PC 76</td>
<td>&quot;</td>
<td>♂</td>
<td>300</td>
<td>(44 days)</td>
<td>22. xii. 38</td>
<td>Colour</td>
</tr>
</tbody>
</table>

feeding, the other died on the 35th day. The birds were in a perfectly healthy condition during the first two-thirds of feeding period, but they became quite inactive during the last third. At the same time loss of body weight and the development of mucus obstruction in the mouth occurred. However, these pathological conditions did not seem to affect the growing feathers, since the growth rate was considerably accelerated by excessive thyroid stimulation and the feather vane was completely formed before the appearance of these symptoms. Hence changes occurring in the feathers could be attributed to the direct effect of hyperthyroidism on the follicles.

The effect of thyroid feeding on the growing feathers was consistent in the two cases. Excessive deposition of melanin and full development
of barbules were seen in the feathers of these regions normally white and deeply fringed. As a result the plumage as a whole displayed a uniform pattern of solid black, but the breast feathers, in contrast to the solid black of the normal, became much lightened.

An interesting result from the thyroid gland-fed birds was the production of white bars in feathers of different regions. This was most marked on the saddle and back, least on the wing bow and neck, and least on the breast. Microscopic examination of feathers revealed extensive formation of barbules in the decoloured area and the reversion of pigment from black to white and vice versa was very sharp. The significance of this deserves further consideration.

Rocks. Two Barred Rock males and one White Rock male were fed with desiccated thyroid. Regions were demud as a routine on the day on which feeding was started. The dosage was 300 mg. per day. The Barred Rocks were killed after a period of treatment of 83 days and the White Rock on the 82nd day. Regenerated feathers from different regions were plucked and preserved for examination.

No colour changes were appreciable in these birds, but barbules were fully developed in those feathers which normally lacked them. Instead of having narrow, pointed, and lacy contours, the saddle feathers became broad, rounded, and solid like those of the female.

Mallard. Two mallard drakes in nuptial plumage were subjected to thyroid gland treatment. Before the beginning of treatment, the left half of the body was entirely deplumed, leaving the right half for comparison with the regenerated feathers. After a period of 43 days of treatment with 300 mg. of desiccated thyroid substance daily, the dosage was increased to 600 mg. Samples of regenerated feathers were plucked from the left side and the right side was deplumed at the commencement of the second feeding period. The treatment was carried out for another period of 44 days, by which time the regenerating feathers on the right side had completed growth and were plucked for study. Observation was continued on the newly growing feathers after the cessation of feeding.

Feathers of the dorsal areas were obviously not affected by the lower dosage, but those of the ventral surface, from the crop region backward, appeared to have a modified colour pattern. This consisted in the formation of black bars at regular intervals. The barred pattern was evidently due to abnormal accumulation of melanin, which in normal birds is only present as fine stipules (as in the keel feathers) or entirely absent (as in the crop feathers). Increasing the doses of thyroid substance from
300 to 600 mg. daily did not increase the intensity of melanin deposition to any appreciable extent. The barred pattern disappeared again in feathers growing after the cessation of feeding with thyroid substance.

**DISCUSSION**

In comparing the results with the classification of thyroid reactions given in the introduction it is evident that the Rocks, Barred, White and Black, may be considered as belonging to Group C, the Rhode Island Red type; neither thyroidectomy nor thyroid gland feeding affected the colour or pattern of their plumage, and the structural modifications which ensued under these conditions indicate that the sexual plumages of these breeds reflect different levels of thyroid functioning in the male and female.

In the duckwing game bantam, though thyroidectomy reduced the plumage of both sexes to a basic type, administration of the desiccated gland to males resulted in an all-black bird and not in the female pattern of lightly pencilled grey. The white barring which occurred on the birds suggests that the dosage was excessively high, and it is possible that lower doses might have induced an approach to the female pattern. On the other hand, the intervention of the ovary to complete this pattern may be necessary here, as it is in the Brown Leghorn, and it is not clear, therefore, whether the duckwing belongs to Group A or Group B.

Thyroidectomy of partridge game bantam females suggested that they behave similarly to their large prototypes, the Brown Leghorns.

In the pigeon, thyroidectomy was without influence on the colour, but the feather structure reacted as in the fowl.

In the mallard, both colour and structure reacted to thyroid administration. The increase in melanin in the ventral feathers, which occurred in bars, suggests a tendency towards the female or eclipse type; but even with higher dosage this was not completely achieved and the dorsal feathers were never affected. Thus it appears that other agents must play a much more important part than the thyroid gland in the production of sexual plumage in the drake.

**SUMMARY**

1. The effects of hypothyroidism, produced by thyroidectomy, and of hyperthyroidism, produced by feeding dried gland, have been studied in various breeds of fowl, in ducks and in pigeons.
2. In duckwing and partridge game bantams thyroidectomy caused dramatic changes in the structure and colour of the plumage, which lost sex dimorphism and regionalization.
3. In Barred, White and Silver-Black Rocks thyroidectomy resulted only in the reduction of barbules without any alteration in the colour of the plumage.

4. In the male mallard, thyroidectomy had some effect, the colour pattern of the dorsal feathers being changed to that characteristic of the ventral feathers.

5. In the pigeon, thyroidectomy appeared to have no effect on colour pattern, but the structure of the feathers was altered.

6. Under conditions of hyperthyroidism, the plumage changes were in the opposite direction to those seen with hypothyroidism. Thus, in the Rocks (Barred and White), a full development of barbules was seen in those feathers which were normally deeply fringed. In the male mallard, melanin deposition was somewhat increased in the ventral feathers. In duckwing bantam males there was excessive development of barbules and heavy deposition of black pigment.

7. The significance of the thyroid gland in the production of sex dimorphic plumage is discussed.

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