EFFECTS OF SEX HORMONES ON PLUMAGES OF THE BLUE-WINGED TEAL[1]

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A relationship between sex hormones and plumage characters is well established (cf. Assenmacher, 1958 and Voitkevich 1966). Of particular interest in waterfowl is the similarity between female plumages and the femalelike eclipse (basic) plumage of males of sexual dimorphic northern hemisphere anatids. Goodale (1910) found that ovary removal in the Rouen Duck (*Anas platythynchos*) resulted in assumption of the male breeding plumage, and Van Oordt (1931) also supported the theory that the female plumage of the domestic duck (*A. platythynchos*) was produced under ovarian influence.

The dependence of the eclipse plumage of the male Mallard (*A. platytyrhynchos*) on the testes has been shown by Goodale (1916), Walton (1937), and Emmens and Parkes (1940), although they did not implicate a particular hormone. Höhn and Cheng (1967) demonstrated an abundance of estradiol at the time of eclipse plumage development in the Mallard. Emmens and Parkes (1940) and Witschi (1961) were able to feminize male plumages with estrogen administration but were not able to influence feather patterns of the male with testosterone injections.

The purpose of this study was to investigate hormonal influences on sexual dimorphism in the Blue-winged Teal (*A. discors*). This species was selected because it is strongly sexually dimorphic, easily handled in captivity, and its plumages have not been studied. Plumage terminology follows Humphrey and Parkes (1959).

METHODS

Feather plucking.—Feathers were plucked several days before starting experiments to assure feather development while hormone levels were elevated. Feathers were plucked from areas that show obvious sexual dimorphism: face (included posterior part of the white crescent of the male), chin-throat, chest-center, chest-side, side, flank, lower tail coverts, and scapulars. The face and chin-throat areas were about ¼ inch^2: while the other areas were about ½ inch^2.

Hormone administration.—Diethyl stilbestrol was used for estrogenic activity. Three- and 6-mg "stimplants" (Charles Pfizer and Co., Inc., Brooklyn, New York) were implanted subcutaneously in the nape with a Pfizer Automatic Implanter. Control birds received the same treatment with an unloaded implanter.

Testosterone was administered by one of two methods. In the first experiment, 1 mg of testosterone propionate (Upjohn Co., Kalamazoo, Michigan) in 0.2 cc

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cottonseed oil was injected subcutaneously in the nape daily. Control birds received daily injections of 0.2 cc cottonseed oil. Because birds receiving daily injections developed irregular and interrupted molt patterns and their plumages became badly worn, injections were discontinued in subsequent experiments in favor of testosterone pellets. We cut 75-mg testosterone pellets, Oreton (Schering Corp., Bloomfield, New Jersey), into five parts of approximately 15 mg each, made a puncture in the skin of the nape, and inserted the pellets with forceps. Control birds also were subjected to skin puncture and forceps insertion.

Gonadectomy.—Birds were taken off feed 24 hours and water 12 hours before surgery because empty viscera made the gonads more accessible. Commercial coagulants were administered to reduce hemorrhage during surgery. In the first experiment, birds were given a synthetic vitamin K product, Clotin (Gland-O-Lac Co., Omaha, Nebraska), for 3 days before surgery. Birds gonadectomized for the final experiment were given a preparation of oxalic acid, Vetistat (Norden Laboratories, Inc., Lincoln, Nebraska). This was injected intramuscularly about 45 minutes before operating.

Birds gonadectomized for the first experiment were not anesthesized. During subsequent gonadectomies birds were anesthesized with Equithesin (Jensen-Salsbery Laboratories, Kansas City, Missouri), a combination of choral hydrate, pentobarbital, and magnesium sulfate in aqueous solution of propylene glycol with 9.5 percent alcohol. This was administered by intramuscular injections at a dosage of 2.5 cc per kg of body weight as recommended by Gandal (1956).

Gonads were removed through incisions on the upper side between the last two ribs. Testes were removed with a large pair of forceps that had two small pieces (5/16 × 3/16 inches each) of 1/16-inch stainless steel silver-soldered at right angles to the ends. Ovaries were removed with an equature (snare) made from a 1/4-inch stainless steel rod. A piece of 1/16-inch stainless steel containing two small holes was soldered to one end, and platinum wire looped through the holes.

Feather pattern terminology.—In sexually dimorphic anatids, females often are characterized by plain feathers or by dark U-patterns on light background, whereas males often have V-patterns. The point of the pattern is directed toward the proximal end of the feather. Modified U's refer to an intermediate condition between U's and spotting. The dark outer and inner portions of U-patterned feathers become broken into spots. They are called modified U's if the spots are close together essentially in the pattern of the U and modified spots if the pattern is closer to a spotted feather.

Effects of Various Treatments on Feather Regeneration of Immatures

This experiment was begun to determine the effects of gonad removal and sex hormone administration on pattern and color of regenerated feathers. It used 20 male and 20 female immature Blue-winged Teal essentially in juvenal plumage, but with some first basic feathers in the chest and side. Five birds of each sex had been gonadectomized on 1 October 1967 when 82 days old; of the remainder 5 males and 5 females received 6-mg implants of diethyl stilbestrol, 5 males and 5 females received daily injections of 1-mg testosterone propionate in 0.2 cc cottonseed oil, and 5 males and 5 females were controls. Two control males

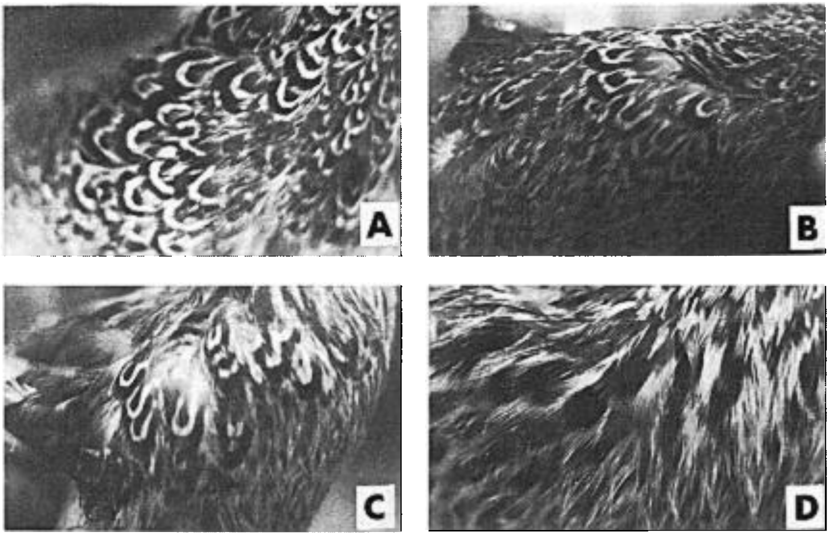

Figure 1. The effects of castration, testosterone propionate, and diethyl stilbestrol on regeneration of chest-side feathers of immature male Blue-winged Teal. A, controls; B, castrate; C, testosterone treatment; and D, diethyl stilbestrol treatment.

and 3 control females were treated with an empty implanting gun, and 3 males and 2 females received 0.2 cc cottonseed oil injections daily.

Birds were plucked and hormone administration was begun on 7 October 1967. Daily injections were planned until all plucked areas had regenerated feathers, but several feather tracts were slow to regenerate, and waiting for regeneration would have necessitated comparing feathers grown at widely spaced intervals.

Birds were examined between 5 and 14 November, about 1 month after plucking. Because many areas had not regenerated feathers at that

TABLE 1
NUMBER OF AREAS FAILING TO REGENERATE FEATHERS AFTER 30 DAYS[1]

Treatment	Males	Females
Controls	0	3
Gonadectomy	1[2]	5[2]
Diethyl stilbestrol	6	10
Testosterone	19	20

[1] Out of 30 total areas (6 areas/bird; 5 birds).
[2] Out of 18 total areas (6 areas/bird; 3 birds).

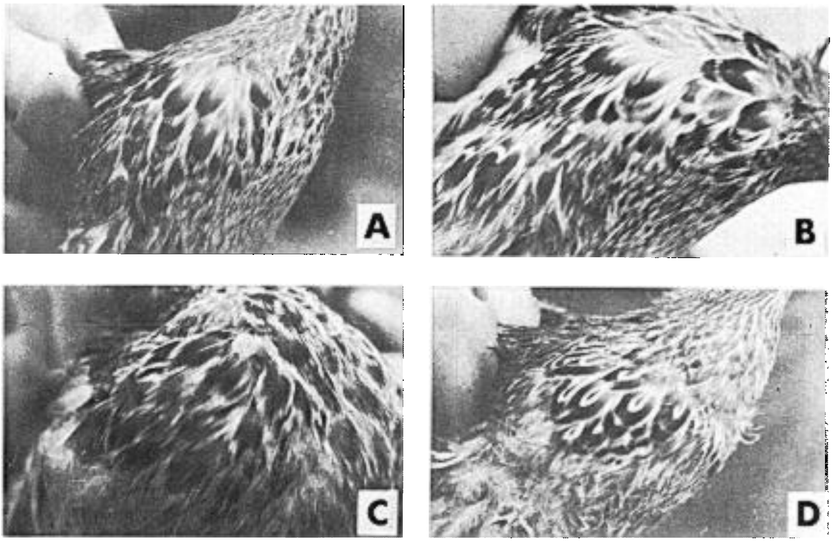

Figure 2. The effects of gonadectomy, testosterone propionate, and diethyl stilbestrol on regeneration of chest-side feathers of immature female Blue-winged Teal. A, controls; B, ovariectomy; C, diethyl stilbestrol treatment; and D, testosterone treatment.

time (Table 1), tracts were examined again on 10 December, 60 days after plucking. The face and chin-throat regenerated most completely, and the flank and lower tail coverts failed to regenerate most frequently.

In males, regenerated feathers of the face and chin-throat were the same for all treatments and resembled those originally plucked, although the new feathers possibly were lighter. Regenerated lower tail coverts were quite similar in all treatments—varying from spotted to dark mottled. Feathers regenerated on the chest, chest-side, and side were patterned with U's in the controls, castrates, and testosterone treatment, while those of diethyl stilbestrol-treated birds were plain (Figure 1).

In females, regenerated feathers of the face and chin-throat were the same for all treatments, and the lower tail coverts were the same for three treatments but were not regenerated by the testosterone-treated birds. Regenerated feathers of the remaining areas were essentially plain in the controls and diethyl stilbestrol treatment, while those of ovariectomized and testosterone-treated birds were patterned—mostly with U and V markings (Figure 2). Of the ovariectomized birds, one regenerated mostly plain feathers, and the other two regenerated mostly patterned feathers. Although these birds were not laparotomized, I suspect that the patterned feathers represent more complete ovariectomy.

TABLE 2

EFFECTS OF CASTRATION, DIETHYL STILBESTROL, AND TESTOSTERONE PROPIONATE ON PENIS LENGTHS OF IMMATURE BLUE-WINGED TEAL

Treatment	No. of days following treatment	N	$\overline{X}$ (mm)	Range (mm)	SE	Penis condition
Control	7 or 9	5	2.4	2–3	0.25	White, straight
Castrates	7	3	2	2–2	0.00	White, straight
Diethyl stilbestrol	7	5	4	3–5	0.45	White, straight
Testosterone propionate	9	5	8.6	7–12	0.90	Red, coiled

EFFECTS OF VARIOUS TREATMENTS ON OTHER STRUCTURAL CHARACTERS

Subsequent plumages of some birds were followed after completion of the experiment. Birds receiving daily injections (testosterone treatment and injected controls) were excluded because their plumage and molt patterns were atypical. Females were excluded because of the difficulty of relating feather patterns to plumages for all areas.

Both control birds developed two complete alternate plumages during winter and spring. They were essentially alternate by early February and were in prebasic molt on 30 March 1968. The resulting basic plumage was nearly complete when the birds began prealternate molt, and they were in alternate plumage by 23 May 1968. Infrared heat lamps used to heat the building during the winter (December–March) probably caused this unusual molting pattern.

Diethyl stilbestrol-treated males molted into basic plumage and remained basic through 23 May, at which time two of the three remaining birds were in molt. This molt involved the head, body, and tertials, which is expected procedure for prealternate molt, but the incoming feathers were basic. The omission of alternate feather patterns probably was caused by stilbestrol or the infrared heat lamps.

Castrates molted into basic plumage and were still basic on 23 May. They remained in basic plumage throughout summer and fall and began prealternate molt in February 1969. In early March, the two castrates (one died earlier) were about half alternate and half basic. A laparotomy on 5 March 1969 revealed an absence of testicular tissue on both sides of both birds. They assumed the alternate plumage in late March–early April, at which time penis lengths were still between 2 and 3 mm.

Penises were measured periodically from initiation of the experiment through 23 May 1968. After one week, penis lengths of testosterone-treated birds were greatly increased (Table 2). The penis lengths of diethyl stilbestrol treated birds were slightly longer than those of controls

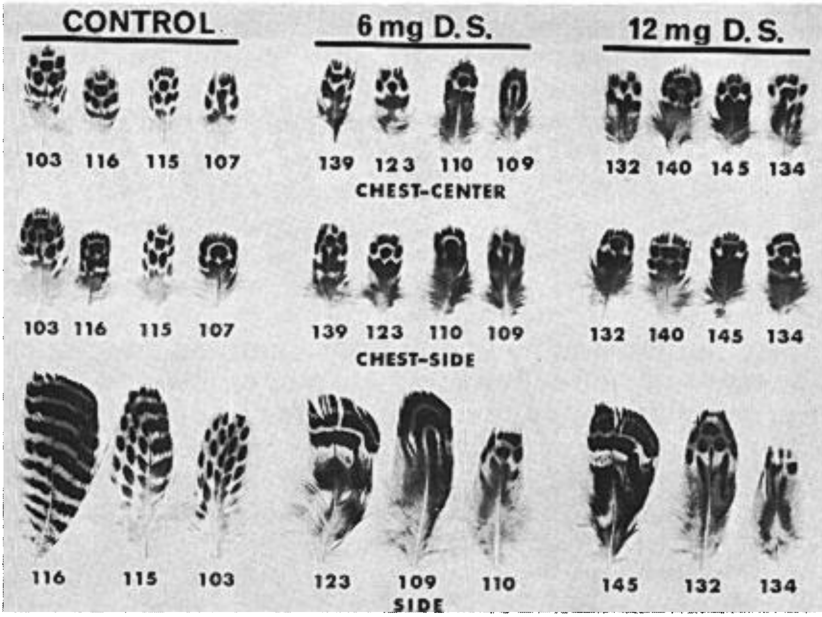

Figure 3. The effects of 6- and 12-mg diethyl stilbestrol implants on regenerated feather patterns of the chest-center, chest-side, and side of adult male Blue-winged Teal.

7 days after implantation. When measured 1 month later (early November), penises of controls had not changed noticeably, while those of diethyl stilbestrol-treated birds were slightly smaller. These data suggest that diethyl stilbestrol may have initially caused an increase in penis size. After 5 months of treatment, penises of control birds were about 12 mm long and those of stilbestrol-treated birds were about 7 mm long. Penises of castrates were measured through May 1969, 20 months after castration, and were never longer than 3 mm.

Hormonal treatments also influenced bill spotting of females, although such records were not originally considered part of the experiment. Ovariectomy and the administration of testosterone and diethyl stilbestrol seemed to reduce the number of bill spots. Ovariectomized birds averaged 6 spots (0–16; N = 3), diethyl stilbestrol-treated birds averaged 4.4 (0–12; N = 5), and testosterone-treated birds averaged 10.4 (3–32; N = 5). Individual values for the testosterone-treated birds were between 3 and 7 except for 1 bird with 32. (This individual also was the only bird to regenerate no feathers.) The average number of bill spots of control birds was 24.6 (2–44; N = 5). Four of these birds had well over 20 spots, and 1 bird had only 2.

TABLE 3
EFFECTS OF DIETHYL STILBESTROL ON PATTERNS OF REGENERATED FEATHERS

	6 mg diethyl stilbestrol		18 mg diethyl stilbestrol	
Area	Control	Treatment	Control	Treatment
Face	Black, white in crescent	Black, white in crescent	White, with brown streaks	White, with brown streaks
Chin-throat	Black	Black	White	White
Chest-center and chest-side	Spotted	U or irregular patterns	Spotted	Plain or irregular patterns
Side	Spotted or barred	U or irregular patterns	Spotted or barred	Plain or irregular patterns
Flank	White	White	White, (few barred)	Tan—plain or mottled with dark, and irregular patterns
Lower tail coverts	Black, some gray mottling	Mottled gray	Black, one with dark irregular blotches	Tan with irregular patterns, some dark blotches
Scapulars	Blue vane, light shaft streaks, or irregular patterns	Buff band followed by plain brown	Blue vane, light shaft streaks, or weak patterns	Plain brown, few irregular patterns

EFFECTS OF DIETHYL STILBESTROL ON FEATHER PATTERNS AND MOLT OF ADULT MALES

Results of the experiment with immature teal indicated that diethyl stilbestrol would suppress spotting and V patterns characteristic of males. To test this observation further, an experiment was begun using 15 adult male Blue-winged Teal about 18 months old. The birds, in various stages of prealternate molt, were divided into 3 groups of 5 each such that each group contained birds in similar plumage condition. Feathers were plucked on 26 December 1967. On 6 January 1968, 11 days after plucking, one group received 6-mg implants of diethyl stilbestrol, a second group received 12-mg implants of diethyl stilbestrol, and the controls were treated with an unloaded implanting gun.

Because the 6- and 12-mg treatments proved only partly effective in modifying feather patterns, another experiment was begun to compare controls with treatments of 18 and 24 mg of diethyl stilbestrol. Feather plucking and stilbestrol implanting took place on 18 August 1968. Most of the 15 birds used in this experiment were in basic plumage, several

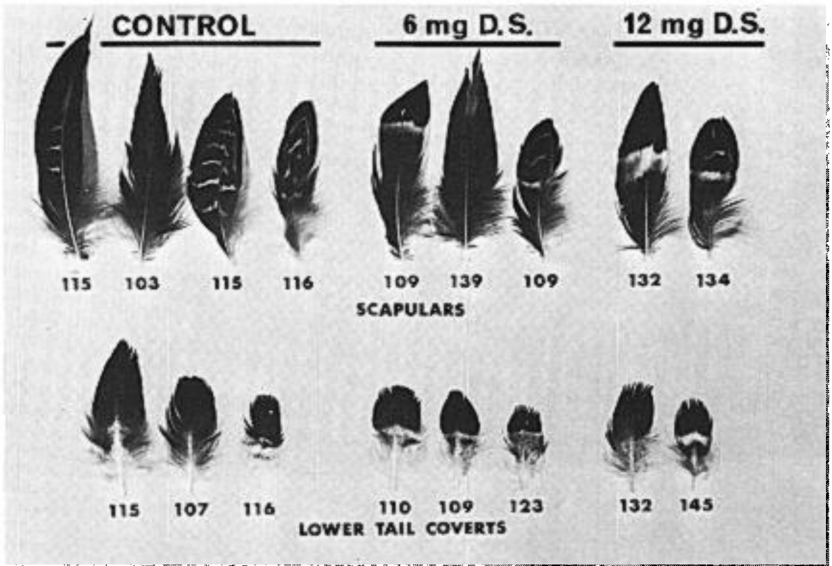

Figure 4. The effects of 6- and 12-mg diethyl stilbestrol implants on regenerated feather patterns of the scapulars and lower tail coverts of adult male Blue-winged Teal.

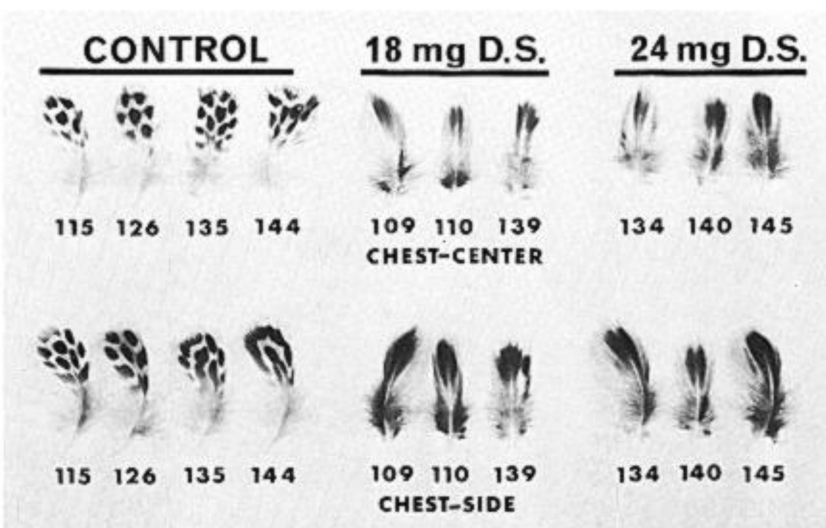

Figure 5. The effects of 18- and 24-mg diethyl stilbestrol implants on regenerated feather patterns of the chest-center and chest-side of adult male Blue-winged Teal.

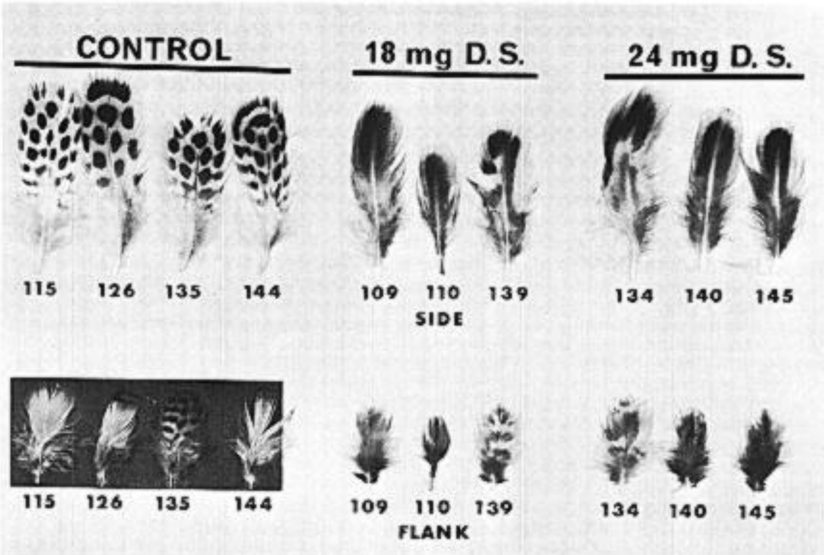

Figure 6. The effects of 18- and 24-mg diethyl stilbestrol implants on regenerated feather patterns of the side and flank of adult male Blue-winged Teal.

were in early prealternate molt, and three were in late stages of prealternate molt.

Effects of diethyl stilbestrol on feather patterns.—Patterns of regenerated face and chin-throat feathers of birds at all stilbestrol concentrations were like the controls of their respective treatments (Table 3). Patterns of regenerated feathers in the remaining areas of the 6- and 12-mg treatments were like the controls distally and modified proximally (Figures 3 and 4). At 6- and 12-mg levels, patterns were modified but melanization was not markedly depressed. With the scapulars and to a lesser extent the lower tail coverts, a buff band formed across the feather at what appears to be the point where stilbestrol initiated its effect.

With 18- and 24-mg of stilbestrol, patterns were almost completely suppressed (Figures 5 and 6). The lower tail coverts regenerated black feathers in the controls and light tan feathers with some dark mottling in both treatments.

Effect of diethyl stilbestrol on molt.—The administration of diethyl stilbestrol had a pronounced inhibitory effect on molt (Table 4). In January, after completion of the feather regeneration experiment, all birds were in alternate plumage and were not molting. The birds were last checked on 31 March (84 days after stilbestrol implantation) and

TABLE 4

EFFECT OF DIETHYL STILBESTROL ON MOLT

Days after implant.	Controls				6 mg d. s.				12 mg d. s.			
	Plumage aspect			No. in molt	Plumage aspect			No. in molt	Plumage aspect			No. in molt
	Alt.	Int.	Bas.		Alt.	Int.	Bas.		Alt.	Int.	Bas.	
0	5			0	5			0	5			0
52	4	1		5	4[1]			2	4[1]			0
84	0	2[1]	2	4	1	2	1	4	4			2

[1] One died.

the birds of the 12-mg treatment were just beginning to molt. While stilbestrol inhibited molt into the next plumage, it did not suppress regeneration of plucked feathers.

EFFECT OF DIETHYL STILBESTROL AND TESTOSTERONE ON FEATHER REGENERATION OF GONADECTOMIZED ADULTS

Feather plucking and hormone administration provided excellent evidence of hormonal influences on feather patterns, but blood hormone levels attributable to normal gonad secretion were not known. It was decided, therefore, to eliminate normal hormone production as a bias by using gonadectomized adult teal.

Feathers were plucked between 1 and 2 weeks after gonadectomy, on 28 and 29 September 1968. In addition to the areas described previously, the rump also was plucked. On 3 October, the birds were placed into three groups of 14 (7 males and 7 females). One group received 15-mg diethyl stilbestrol implants, a second group received 15-mg testosterone implants, and controls were treated with an unloaded implanting gun.

Females were in basic plumage and not molting while males were in various conditions of plumage and molt. Birds were divided such that each group contained birds in similar plumage condition.

Most feather regeneration was completed in 1 month. Laparotomy of five birds that died during the experiment revealed an absence of testicular tissue during the period of feather regeneration.

Controls.—Control (castrated) males regenerated alternate feathers in most areas. Two birds, in basic plumage when plucked, regenerated alternate feathers in all areas except the face and chin-throat, which were basic.

Feathers regenerated by control (ovariectomized) females varied from plain to patterns similar to the male alternate plumage. Two birds

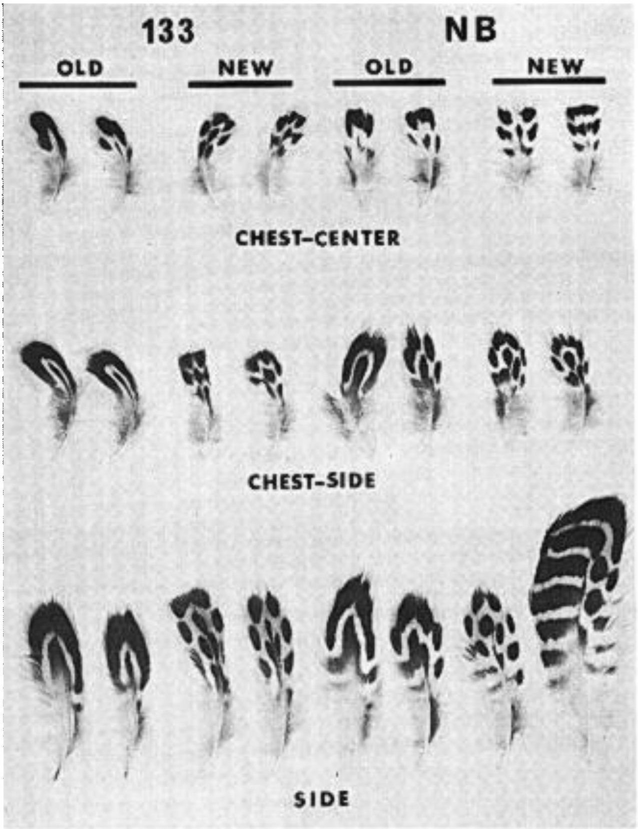

Figure 7. Patterns of feathers regenerated by two (133 and NB) control ovariectomized Blue-winged Teal. Laparotomy revealed very little regenerated ovarian tissue in these birds.

(NB and 133) regenerated face and chin-throat feathers typical of females, while feathers of the chest-center, chest-side, and side were identical to male alternate (Figures 7 and 8). Patterns of regenerated flank feathers of NB were white like male alternate and those of 133 were spotted distally and white proximally. The regenerated lower tail coverts of NB were black like male alternate and those of 133 had irregular dark blotches like those of the male first basic plumage. Patterns of regenerated scapulars were not so pronounced as male alternate, but more malelike than femalelike.

Two control females regenerated feathers that were plain or with U patterns that were nearly identical to the plucked feathers. The other three birds grew feathers somewhat more patterned.

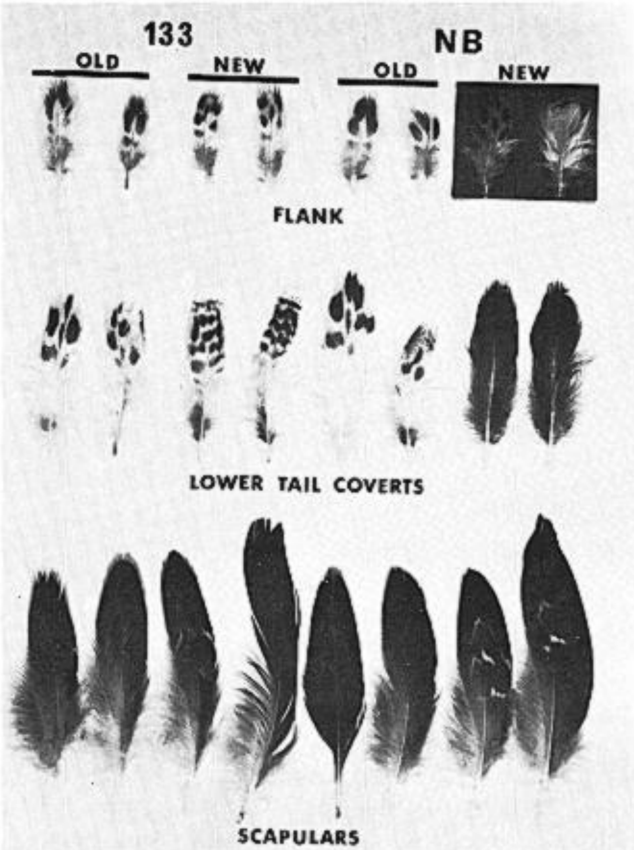

Figure 8. Patterns of feathers regenerated by two (133 and NB) control ovariectomized Blue-winged Teal. Laparotomy revealed very little regenerated ovarian tissue in these birds.

The control birds were laparotomized 10½ weeks after ovariectomy to observe the condition of the ovaries. Of the two birds that regenerated male alternate feathers, NB had a small cluster (3 mm diameter) of follicles, while no regenerated ovarian tissue was found in 133. The two birds whose regenerated feathers were plain or with U patterns had well-developed ovaries. The remaining three birds regenerated ovarian tissue of a size intermediate to the extremes just described. I assumed, therefore, that ovarian hormone production was sufficient to prevent the developing feathers from being patterned like male alternate. Regenerated ovarian tissue was found on the mesenteries of some birds. Thus, it is possible for ovarian tissue to be present, but not visible by laparotomy.

Figure 9. Patterns of chest-center, chest-side, and side feathers regenerated by male (B15) and female (B/B B/B) diethyl stilbestrol-treated gonadectomized Blue-winged Teal. These birds were in alternate plumage when plucked.

Testosterone treatment.—The regenerated feathers of testosterone-treated male castrates were quite similar to those of the control castrates in being mostly male alternate. No effect could be attributed to testosterone. Alternate feathers were regenerated by all birds except one that regenerated basic face and chin-throat feathers and lower tail coverts like the first basic plumage. This bird was in full basic plumage and not molting when plucked.

Feather patterns of testosterone-treated females were the same as those observed in untreated ovariectomized birds. The areas that regenerated feathers noticeably different from those originally plucked were the chest-center, chest-side, and side. The new feathers from these areas had modified U's and spots. The amount of spotting was greatest in those birds in which ovariectomy was most complete.

Diethyl stilbestrol treatments.—The effect of 15-mg diethyl stilbestrol implants on feathers of gonadectomized adult teal was pattern suppression. Feathers regenerated by males were very similar to those of the 18- and 24-mg diethyl stilbestrol treatments described earlier, but in this experiment several birds regenerated weakly patterned feathers in addition to plain feathers.

Plain feathers were regenerated by male and female teal in prebasic molt or having recently completed prebasic molt when plucked. The regenerated chest-center, chest-side, and side feathers were dark brown with light borders, and most were light centrally and with light shaft streaks. The new flank feathers, lower tail coverts, and scapulars were similar in both sexes, but varied more than did those on the chest and sides.

Both plain and weakly patterned feathers were regenerated by male and female teal in prealternate molt or having recently completed prealternate molt when plucked. The new chest-center, chest-side, and side feathers of males had the pigmented areas interrupted, while those of females were more plain (Figure 9). In females, side feathers tended to be more patterned than were chest feathers. The new flank feathers and lower tail coverts of males had similar mottling (Figure 10). In females, these areas regenerated feathers that resembled the chest and sides. The new scapulars had scattered light mottling. This mottling was most pronounced in males and, in some instances, formed large, wide U's, which were not found on the scapulars of wild birds in any plumage, but were similar to the U's found on the scapulars of many females in alternate plumage.

Feathers regenerated on the rump and upper tail coverts also demonstrated that diethyl stilbestrol suppressed feather patterns. Of 6 control (ovariectomized) females, 5 regenerated patterned feathers and 1 regenerated plain feathers. Patterns were most pronounced in those birds with known ovarian regeneration. Four of the diethyl stilbestrol-treated birds regenerated plain feathers and one regenerated patterned feathers. Results in the testosterone treatment were not so clear cut; four birds regenerated patterned feathers and three regenerated plain feathers, but the patterns were very weak.

DISCUSSION

Gonadectomy resulted in an increase in the amount of patterns of regenerated feathers by both sexes. Immature Blue-winged Teal, castrated while in juvenal plumage, molted into first basic plumage and retained this plumage for 16 months (4–6 months longer than in wild birds).

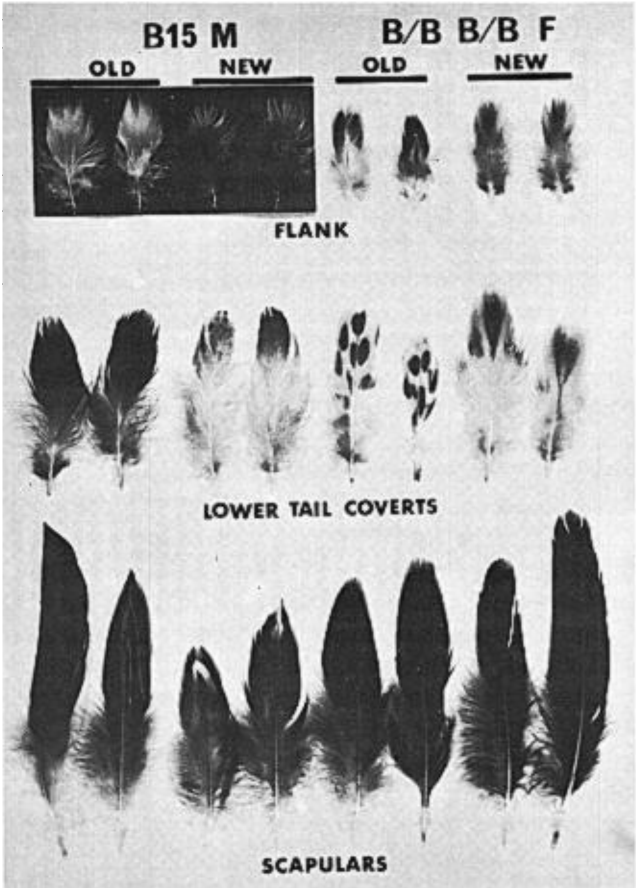

Figure 10. Patterns of flank, lower tail coverts, and scapular feathers regenerated by male (B15) and female (B/B B/B) diethyl stilbestrol-treated gonadectomized Blue-winged Teal. These birds were in alternate plumage when plucked.

Castrated adult birds would be expected to enter prealternate molt much earlier. Although few data are available on castration of immatures, Goodale (1910) suggested that castration of young birds caused a retention of youthful characters. When the birds finally entered prealternate molt, laparotomy revealed no visible testicular tissue. Höhn (1947) reported that Mallards were molting into mating plumage while lacking tubular reactivation in the testes.

Ovariectomy was much more difficult than castration. What seemed a complete ovariectomy was followed in several instances by much regeneration of ovarian tissue. Complete ovariectomy, however, resulted in the regeneration of malelike feathers in all areas except the face and chin-throat. This is consistent with the finding of Van Oordt (1931) that female plumages of the domestic duck are under the influence of the ovary. Response in teal varied between areas of different birds and within areas of a given bird. For example, all of the new lower tail coverts of bird NB were black, while only two of the new flank feathers were white.

Administration of diethyl stilbestrol suppressed feather patterns of immature and adult birds of both sexes. The feminizing of male plumages by diethyl stilbestrol was dramatic and agrees with findings of Emmens and Parkes (1940) and Witschi (1961) on the Mallard. The appearance of buff stripes on feathers in early development at time of estrogen implantation also was obtained with Rouen Ducks by Mueller (1970). Feathers of the face and chin-throat, however, regenerated rapidly, and their patterns were not easily modified. Possibly these feathers completed their growth before the blood estrogen levels rose to threshold (they were plucked 11 days before hormone treatment) or their estrogen threshold was not reached. Lillie (1932) and Assenmacher (1958) stated that rapidly growing feathers have high threshold levels.

A few feathers were grown on the chest, chest-center, and side of some wild females while nesting (during early June). These feathers were nearly identical to those regenerated under the influence of 18- and 24-mg implants of diethyl stilbestrol. They were dark mottled—mostly plain but some with irregular patterns—and were unlike those of the alternate or basic plumages. This suggests a high estrogen level in June. Because feathers with these patterns are not commonly found on wild birds, it seems that they do not undergo extensive molting at this time.

First basic plumage.—Feather patterns of the first basic plumage are highly variable—at least in certain feather tracts. In many instances, chest-center, chest-side, and side feathers resemble those of the juvenal plumage, and in others they are quite similar to those of the alternate plumage. Feathers grown during August seem less patterned than those grown later in the fall. This variation undoubtedly is caused by the time of molt and presumably is associated with gonad development. Immature teal examined during migration frequently are in some stage of prebasic molt but are not actively molting. This intermediate condition suggests an interrupted molt. Immature teal that have nearly finished this molt can be found in August, and for this reason I suspect that late-hatched teal have more highly patterned first basic plumages.

Alternate and basic plumages of adults.—The alternate and basic plumages of males are dramatically different, and no intermediate types occur. Thus it seems that developing male plumages will be alternate until the estrogen level reaches a certain value, at which time basic patterns develop. The results of Höhn and Cheng (1967) support this idea. They found testosterone-estradiol ratios in the testes of Mallards to change from highly in favor of testosterone in April to approximately equal amounts in late May and June. One bird had an excess of estradiol in late May. Oring (1968) found that adult male Blue-winged Teal are capable of depositing pigment for the basic plumage from approximately 19 May to 8 August. These dates also correspond to peak testicular activity in the Mallard (Höhn, 1947). The explanation of basic plumage induction and estrogen secretion during peak testicular activity may lie in the closely related biosynthesis of male and female sex hormones (Voitkevich, 1966). Voitkevich states that, at high concentrations, part of the male sex hormone is transformed into female sex hormone.

Peak testicular activity of the Blue-winged Teal also would be expected just before prebasic molt of adult males, which begins between the first week and the end of June. During the summer of 1967, I observed prebasic molt in northwestern Iowa. Some parts of the birds were half alternate and half basic by the first week of July, indicating that basic feathers were being produced at least from the middle of June. Bennett (1938) stated that most drakes in northwestern Iowa were in prebasic molt by 20 June.

Alternate and basic plumages of females are much more similar than those of males. It seems that feather patterns of female plumages are determined by estrogen and testosterone levels also, but there do not seem to be threshold levels at which one or the other plumage develops. Intergradations of feather patterns are common in females, particularly on the vent.

My data suggest that the spotted and interrupted feather patterns found on the vent and the patterned feathers of the dorsum of females reflect lower estrogen levels in relation to testosterone levels than do the plain and weakly patterned feathers. Furthermore, it seems that estrogen induces plain feathers, and that patterns of U's, modified U's, or spots reflect decreasing levels of estrogen. Thus, feather patterns of females suggest that ovarian secretions from December to April are low in estrogen or high in testosterone and that estrogen levels are higher from May to August.

The prebasic molt is more complete than is the prealternate molt and also occurs in a shorter time. Therefore it seems likely that some mechanism operates to prevent prebasic molting until reproduction is completed. Because this molt comes at about the time of gonadal collapse, it seems likely that decreasing sex hormones may help trigger the onset of molt. Because stilbestrol did not suppress feather regeneration from plucked areas, its main action in inhibiting molt must be in preventing the loss of old feathers. This agrees with the findings of Assenmacher (1958).

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SUMMARY

The influence of sex hormones on plumages and molts of the Blue-winged Teal was studied by experiments with 108 immature and adult birds. Treatments included the administration of 6, 12, 15, 18, and 24 mg of diethyl stilbestrol, daily injections of 1 mg testosterone propionate, 15-mg testosterone implants, and gonadectomy. Before the experiments, feathers were plucked from the face, chin-throat, chest-center, chest-side, flank, lower tail coverts, and scapulars.

Diethyl stilbestrol suppressed feather patterns in both sexes. Six-mg implants induced plain feathers in immature male teal identical to those regenerated by control females. Implants of 18 and 24 mg induced light and dark irregularly mottled feathers. These feathers are similar to those wild birds grow in June when estrogen levels probably are very high. Diethyl stilbestrol inhibited molt of adult birds but did not affect the regeneration of plucked feathers. This suggests that diethyl stilbestrol inhibits feather loss.

Testosterone did not modify regenerated feathers in males. Injections of 1 mg per day induced feather patterns in immature females nearly identical to those of control immature males.

Castration of males resulted in male alternatelike feathers. Ovariectomy of females, if complete, induced male alternatelike feather patterns. One ovariectomized bird (NB) regenerated the following feathers identical to those of male alternate feathers: spotted feathers on the chest-center and chest-side, patterned scapulars, black lower tail coverts, and white flank feathers.

Developing plumages of adult male teal seem alternate unless the estrogen level is great enough to induce basic feathers. Adult female plumages are always brown, but the basic or alternate pattern probably depends on the ratio of testosterone to estrogen. The patterned alternate

plumage of females reflects high testosterone or low estrogen levels, while the less patterned basic plumage seems a product of estrogen.

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