SEASONAL AND TAXONOMIC DIFFERENCES IN THE SIZE AND ACTIVITY OF THE THYROID GLANDS IN BIRDS[1]

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ABSTRACT

The thyroid glands of the house sparrow and other small birds in the Cleveland region have greater secretory activity during late autumn and winter than during late spring and summer. Evidence for this is the presence, during the winter, of high epithelial cells surrounding the follicles, of smaller follicles, and of lesser volumes and weights of the whole thyroid. Large-sized species have larger thyroids, both absolute and relative to body weight, than do small species. With certain precautions, changes in the size of the thyroids serve as a useful index of inverse variations in secretory activity intra-specifically, but not inter-specifically.

The thyroid hormone is well known to stimulate oxidative processes within cells and thus to affect the rate of energy turnover or metabolism of animals. The secreting activity of the epithelial cells of the thyroid is controlled by the thyrotropic hormone from the anterior lobe of the pituitary; secretions may be either into the follicles for storage, directly into the blood for circulation through the body, or in both directions simultaneously. The action of cold in stimulating thyroid activity and heat in depressing it has been frequently demonstrated experimentally. The thyroid may possibly also exert, either directly or indirectly, an effect on growth, molt, gonad activity, food intake, rate of heart beat, body temperature, and migration, but some of these effects are little understood or controversial (Höhn, 1961). Thyroids actively secreting hormone into the blood commonly have small follicles, and the epithelial cells are high and contain pale rounded nuclei. In the relatively inactive thyroids, the follicles contain considerable colloid, are larger in size, and the epithelial cells are flattened (Höhn, 1950).

Some of the more sophisticated methods for determining thyroid activity measure the rate at which I^{131} is taken up by the gland and secreted into the blood plasma (Hertz, Roberts, and Evans, 1938; Bailey, 1953; and Fink, 1957) or note changes in the color reaction of the thyroid on staining (DesMarais and LaHam, 1962). More commonly the degree of thyroid activity has been determined by measuring the height of the epithelial cells (Watzka, 1934; Küchler, 1935; and Dawson and Allen, 1960), stage of epithelial development dependent on cell height and cell and nuclear configuration (Davis and Davis, 1954; Oakeson and Lilley, 1957), the percentage of secretory epithelium in the gland (Uotila and Kannas, 1952; Wilson and Farner, 1960), size of follicles (Haecker, 1926; Watzka, 1934; and Küchler, 1935), or size of glands (Haecker, 1926; Riddle and Fischer, 1925). There are also various cytological criteria that may be used (Ponse, 1951). In the present study, we hope to show that intraspecifically the height of the epithelial cells in adult birds consistently varies inversely with the size of the follicles and with the volume and weight of the gland as a whole, and to show how these different indicators of thyroid activity vary with the season of the year.

Our interest in the thyroid stems from its possible involvement in the bioenergetics and seasonal acclimatization of birds, particularly of the House Sparrow. In this species, resistance to starvation at $-10°C$ changes from about 11 hr. during the summer to 21 hr. during the winter (Kendeigh, 1934), its maximum ability to metabolize energy for existence during the summer is 1.02 kcal/g/day (Davis, 1955) while in the winter it is 1.31 kcal/g/day (Kendeigh, 1949), and its

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lower limit of temperature tolerance for continuous existence is approximately 0°C during the summer (Davis, 1955) and at least −31°C during the winter (Kendeigh, 1949).

There have been several studies of seasonal changes in thyroid activity of birds, but with confusing results. In the citations given by Wilson and Farner (1960), high thyroid activity is reported for the House Sparrow during both the winter period and the autumn molting period in four out of six studies and in two times out of five during the reproductive period. Likewise in 25 other species there is considerable lack of agreement concerning the time of year when the thyroid activity is high and when it is low. Some of the conflicting reports may be due to differences in the severity of the seasonal changes in climate to which the birds were exposed, which has been demonstrated to be of great importance (Oakeson and Lilley, 1960; Wilson and Farner, 1960). We need to know how the activity of the thyroid varies in the particular locality and population of birds being used in bioenergetics studies.

The thyroid material was collected during 1933 and 1934 in the vicinity of Cleveland, Ohio, partly at the Baldwin Bird Research Laboratory and partly at Western Reserve University. Many of the measurements were made at that time, but the final analysis and interpretation of the data have just been completed at the University of Illinois, supported by a grant from the National Science Foundation.

Mean monthly temperatures at Cleveland, Ohio, varied from −0.4°C in February to 23.6°C in July, 1933, and then to −8.2°C in February and 24.4°C in July, 1934. The photoperiod at this locality varies from a little over 9 hr per day in December to over 15 hr per day in June. Seasonal changes in precipitation and relative humidity are not pronounced.

TECHNIQUE

Bird specimens were killed either in the laboratory by fumes of carbon disulfide and dissected immediately, or in the field by shooting and dissected within 3 hr. Both thyroids were removed from the body, placed on a glass plate beneath a binocular microscope, and the two small parathyroid glands adjacent to the posterior end of each thyroid separated off along with all traces of extraneous foreign tissue. No outside moisture was applied to the thyroids, but the work was done rapidly, allowing time for only the superficial moisture to evaporate.

When the glands were weighed, they were placed together on a chainomatic balance sensitive to a tenth of a milligram. After weighing, the glands were immediately placed in the killing and fixing fluid.

In the volume determinations, all birds were killed by fumes of carbon disulfide. Measurements of diameter were made with dividers without removing the glands from the body but not including the parathyroids. The volume, V, was computed using the formula for a prolate spheroid, $V = 4/3\ \pi\ R\ r^2$, where R is one-half the longer diameter and r is one-half the shorter. The glands were then placed into the killing and fixing fluid.

Regaud's fluid was used for killing and fixation in nearly all the House Sparrow material, but Bouin's fluid was used for all other species. Tissues were sectioned 7 to 10 μ in thickness and stained with Heidenhain's iron haematoxylin.

RELATION BETWEEN CELL HEIGHT AND DIAMETER OF FOLLICLES

Measurements were made in the House Sparrow of histological sections under oil immersion by means of a calibrated ocular micrometer. Two measurements were made to obtain the average diameter of the follicular lumen; these were taken at right angles to each other from the inside edge of the epithelial cells on one side to the inside edge on the other side. The height of the cells was measured from the outside to inside edge. A total of 115 follicles was measured in thyroids from eight birds, these birds being collected in June (2), July (2), October (2), November (1), and January (1). The heights of five cells were determined, on the average, for each follicle. These measurements were made by an assistant, John R. Ferrell.

In order to free the comparisons of variables due to individual differences, environmental effects, time of year, etc., comparisons were made on each bird between follicles in excess of 21 μ diameter and follicles under 21 μ. The size of the follicles was very variable even within the same thyroid, as has been noted by other investigators, but there happened to be few follicles with diameters in the range of 20 to 30 μ.

In every instance, the larger follicles had epithelial cells characterized by smaller average heights and the smaller follicles had epithelial cells of greater heights. The average of the means for the eight individuals was $34.0 \pm 2.66\ \mu$ for the diameter and standard error of the larger follicles and $5.4 \pm 0.19\ \mu$ for their cell heights, compared with the diameter of the smaller follicles, $14.0 \pm 0.75\ \mu$, and their cell heights, $6.9 \pm 0.09\ \mu$. The t-test indicated the differences between the large and small follicles, in both follicle diameters and cell heights, to be significant, with the confidence level $< .001$.

The average outside diameter of the follicles may be calculated from the average inside diameter plus two times the average cell height. For the large follicles this is 34.8 μ and for the small follicles 27.8 μ.

Regression coefficients of average cell height against average inside diameter of individual follicles, calculated for five birds with long series of measurements, varied: 0.076, 0.091, 0.097, 0.106, 0.110, with the extreme values being significantly different. When the regression coefficient is determined using the average diameters and average cell heights of large and of small follicles for the eight birds, the regression coefficient is 0.074 and the equation for the regression line: $\hat{Y} = 6.1 - 0.074\ (X - 24.2)$, when $\hat{Y}$ is cell height and X is follicle diameter, both dimensions in microns.

SEASONAL VARIATION IN DIAMETER OF FOLLICLES

The seasons are separated as follows: *summer*, June, July, August; *autumn*, September, October, November; *winter*, December, January, February; and *spring*, March, April, May.

In the first study of seasonal variations in follicle size, camera lucida drawings were made of all follicles within the microsopic field of view, and several fields of view were taken, mostly at random, on successive sections of the same thyroid. Fields of view were avoided, however, when follicles were not clearly defined. The outside outlines of the follicles were drawn, maximum and minimum diameters of each follicle were measured with dividers and divided by the magnification, and averages were calculated for summer and winter (table 1). From the size of the differences and the number of follicles measured, it appears that winter follicles were certainly smaller than summer follicles in all species except possibly the Tufted Titmouse and Downy Woodpecker. Unfortunately, statistical treatment of the data is not practical, since this and later tables were compiled some thirty years ago and the raw data cannot now be reassembled.

In another study, typical sections from each of several thyroids were selected and the average inside diameter of usually ten of the larger follicles were measured using an ocular micrometer. Although there was some subjective selection of representative follicles to be measured, it is again apparent (table 1) that winter thyroids have smaller follicles than do summer thyroids, including those of the Tufted Titmouse and Downy Woodpecker. It is doubtful, in the House Sparrow, whether the difference between the follicle size during the autumn and winter, or the difference between spring and summer, is significant.

These seasonal changes in diameter of the thyroid differ from those obtained by Küchler (1935), who found in four passerine species, including the House Sparrow, smaller thyroids with higher epithelial cells from spring to autumn and larger thyroids with shorter cells in the winter. The results, however, are in agreement with Watzka (1934), where summer thyroids of the House Sparrow had large follicles and flattened epithelial cells and winter thyroids had small follicles and high epithelial cells. Watzka, however, did not make any extensive quantitative comparison.

TABLE 1

Diameters of thyroid follicles at different seasons

Species	Season	Number of birds	Outside diameters: Number of follicles	Outside diameters: Average in microns	Inside diameters: Number of follicles	Inside diameters: Average in microns
Downy Woodpecker	Summer	1	45	31.0	10	46.1
Dendrocopos pubescens	Winter	1	59	33.0	10	36.1
Black-capped Chickadee	Summer	1	104	35.1	10	53.1
Parus atricapillus	Winter	1	109	27.2	10	32.9
Tufted Titmouse	Summer	1	133	26.7	10	37.2
Parus bicolor	Winter	1	85	25.5	10	29.3
White-breasted Nuthatch	Summer	1	56	38.2	10	52.8
Sitta carolinensis	Winter	1	56	32.6	10	33.2
Robin	Summer	1	—	—	10	65.0
Turdus migratorius	Winter	1	—	—	10	53.0
House Sparrow	Summer	9	681	31.5	120	45.1
Passer domesticus	Autumn	7	—	—	80	30.5
	Winter	4	424	22.0	40	32.3
	Spring	2	—	—	30	43.4
Song Sparrow	Summer	1	—	—	10	55.7
Melospiza melodia	Winter	1	—	—	10	35.5

SEASONAL VARIATION IN VOLUME OF THYROIDS

When the thyroid contains predominantly large follicles, it should be larger in size than when it contains predominantly small follicles, provided the number of follicles, amount of interstitial tissue, etc., remains essentially the same. A comparison of table 2 with the data for House Sparrows in table 1 shows that this is true. The difference between adults and juveniles in the summer, mostly in June and July before the annual molt takes place, is significant (<0.05). During the autumn (October and November) after the molt is completed, adults and immature birds were less certainly distinguished and hence are combined. Three

TABLE 2

Average volume (with standard error) of thyroids of the House Sparrow at different seasons

Season		Number of birds	Volumes of single thyroids, mm³
Summer:	*adults*	6	5.46±1.25
	juveniles	12	3.60±0.58
Autumn		14	4.89±0.47
Winter		14	4.76±0.50
Spring		12	5.29±0.88

birds, obviously immature, had very large thyroids, averaging 6.24 ± 1.20 mm^3, so the smaller-sized thyroids, characteristic of juvenile birds in the summer, no longer holds. The difference in the average volume of thyroids between autumn and winter and between spring and the adults in summer is not significant; the difference between that of summer and winter adults is highly so (<0.001).

Haecker (1926) attempted to show a correlation between the size of the whole thyroids and the average size of the follicles in the Carrion Crow, *Corvis corone*, in Switzerland, although few statistics are given. In general, he found an increase in the volume of the gland and the size of the follicles from June to November and a decrease from sometime during the winter until May or June.

EFFECT OF SEX ON THYROID WEIGHT

Since the activity of the thyroid, as shown by histological criteria, is correlated inversely with the volume of the thyroid, there is reason to expect the volume in turn to be correlated with the thyroid weight. All the weight data were obtained, however, on an entirely different set of thyroids so that direct analysis of the weight-volume relationship is not possible. Before considering seasonal differences in the weight of the thyroids, it is desirable first to analyze the possible modifying role of various other factors. This analysis is done for the summer season only.

The data on sex differences in weight of the thyroids (table 3) are not sufficient for any definite correlation. In three species there is a suggestion that the thyroids are heavier in the male, in five species they may be heavier in the female, and in one species they are about the same in the two sexes. There appears to be no consistent difference in thyroid weight correlated with sex, nor has one been clearly demonstrated for birds in the literature.

TABLE 3

Sex differences in the average weights of the thyroids

Species	Adult male		Adult female	
	Number of birds	Thyroid weight, milligrams	Number of birds	Thyroid weight, milligrams
Black-capped Chickadee	3	0.4	1	0.7
White-breasted Nuthatch	7	1.4	2	1.4
House Wren *Troglodytes aedon*	4	0.6	2	1.0
Red-eyed Vireo *Vireo olivaceus*	3	1.9	1	1.7
House Sparrow	2	2.6	1	3.2
American Goldfinch *Spinus tristis*	2	1.6	1	1.0
Rufous-sided Towhee *Pipilo erythrophthalmus*	6	2.3	2	1.6
Field Sparrow *Spizella pusilla*	1	0.8	1	1.0
Song Sparrow	5	1.5	2	1.6

EFFECT OF AGE ON THYROID WEIGHT

In the precocial domestic fowl, the thyroid contains colloid and apparently becomes functional on the tenth day of incubation (Hopkins, 1935), and one can expect that the relative rate of development is somewhat similar in altricial songbirds. In altricial doves, the follicles are filled with colloid and the cells are flattened immediately before hatching, but one day after hatching the follicles are small and the cells are high as in active thyroids. The glands grow in size during the nestling period with an increase in number of cells and follicles. At first the follicles contain little colloid, but the amount increases until the condition typical of summer adults is obtained when the birds are 10 days old (Watzka, 1934).

A series of weights taken of nestling House Wrens indicates that the thyroid glands reach the size found in the adult bird when the nestling is 7 days old (table 4). Because of its lesser body weight at this age, the percentage of thyroid to body weight is 0.0098 compared with 0.0064 in the adult. From 14 days through

TABLE 4

Average weight of thyroid glands in House Wrens during different stages of growth

Age, days	Number of birds	Body weight, grams	Thyroid weight, milligrams
2	1	1.998	0.1
3	5	3.392	0.2
4	1	4.883	0.4
5	5	6.254	0.4
6	7	6.557	0.4
7	4	7.139	0.7
8	5	8.238	0.6
9	5	8.360	0.7
10	2	9.442	0.8
11	3	9.498	0.6
12	3	8.842	0.5
13	2	10.300	0.8
14	3	9.490	0.4
15	2	10.550	0.6
Juvenile	1	8.800	0.5
Adult	6	11.000	0.7

the juvenile stage the thyroid appears to decrease in weight, but the lesser weight during this period is not significantly different statistically from that of the adult, perhaps because of the small number of records. Further study is required to determine whether these variations have a physiological meaning.

It is of interest in this connection that in the Vesper Sparrow the height of the epithelial cells, presumably indicating secretory activity, reaches a peak at five days after hatching and then declines to the significantly lower heights characteristic of fledgling birds of 8 to 12 days of age and of adults during the nesting period (Dawson and Allen, 1960). These peaks in the Vesper Sparrow and House Wren come at the time of development of body temperature regulation. In the chick, a precocial species with temperature regulation developed at hatching, no such peak after hatching is evident (Breneman, 1954).

The larger volume of the thyroids in adults compared with juveniles in the House Sparrow is apparently also correlated with a greater weight of the glands in the adults (table 5). The number of data for any particular species is inadequate, but in only one of the seven species (total, all species: 63 birds), where comparisons are made, are the weights of the thyroid greater in the juveniles.

SEASONAL VARIATIONS IN THYROID WEIGHTS

In five of six species where comparisons are possible (table 6), the thyroid weight is less in the winter than in the summer. In the House Sparrow this is true and statistically significant ($<.01$), even when the thyroid weights of adults and juveniles are combined in the summer. In the Song Sparrow, the exception in having the heavier thyroid in the winter, there is only one record.

In another study, Dr. D. P. Quiring, a former colleague of ours, weighed the thyroids and parathyroids of House Sparrows collected in August and December, 1934. Summer thyroid weights of 12 birds averaged 6.7 mg and 31 winter weights averaged 4.6 mg.

TABLE 5

Average weights of thyroids in adults and juveniles during the summer

Species	Adults, both sexes		Juveniles	
	Number of birds	Thyroid weight, milligrams	Number of birds	Thyroid weight, milligrams
Mourning dove				
Zenaidura macroura	1	7.6	1	6.6
Black-capped Chickadee	4	0.5	2	0.7
House Wren	6	0.7	1	0.5
Catbird				
Dumetella carolinensis	3	4.7	1	2.8
House Sparrow	3	2.8	24	2.4
Rufous-sided Towhee	8	2.1	1	2.1
Song Sparrow	7	1.5	1	1.5

Woitkewitsch and Nowikow (1936) state that at Moscow, USSR, there is an increase in thyroid weight together with height of epithelial cells in the House Sparrow from July to December. However, it is improbable that the small differences that he noted in these two dimensions and also in the increase of the inner diameter of the follicles in the winter are statistically significant.

The autumn weight of the thyroids in the House Sparrow agrees more closely with the summer than with the winter weight, contrary to what was found with the volumes. However, the three autumn weights were obtained before October 4 and the autumn volumes were all obtained between October 4 and November

TABLE 6

Seasonal variation in the average weights of avian thyroids

Species	Summer		Autumn		Winter		Spring	
	Number of birds	Thyroid weight, milligrams	Number of birds	Thyroid weight, milligrams	Number of birds	Thyroid weight, milligrams	Number of birds	Thyroid weight, milligrams
Hairy Woodpecker								
Dendrocopos villosus	—	—	1	2.0	1	1.6	—	—
Downy Woodpecker	3	1.4	3	1.6	4	1.2	—	—
Black-capped Chickadee	6	0.6	—	—	4	0.5	—	—
Tufted Titmouse	7	1.5	1	1.7	2	1.4	—	—
White-breasted Nuthatch	9	1.4	—	—	3	1.0	1	1.0
Robin	2	7.9	—	—	—	—	3	7.2
Starling								
Sturnus vulgaris	—	—	2	8.8	—	—	4	6.2
House Sparrow	27	2.4	3	2.3	7	1.6	—	—
Rufous-sided Towhee	9	2.1	—	—	—	—	5	2.1
Song Sparrow	8	1.5	—	—	1	1.8	2	1.2

15. Likewise, the heavy thyroid weights for the Downy Woodpecker and Tufted Titmouse were all obtained before October 12. The spring thyroid weight of the White-breasted Nuthatch is identical with the average winter weight, probably because it was obtained early, on March 20. It appears, therefore, that late autumn, winter, and early spring thyroid weights, as well as thyroid volumes, are less than they are during most of the spring, summer, and early autumn.

This is exactly opposite to what Riddle and Fischer (1925) found in doves, *Columba*, and pigeons, *Streptopelia;* in these birds, thyroid weights averaged greater during autumn and winter than during spring and summer. However, from November to March their caged birds were supplied with artificial heat so that only rarely were they exposed to temperatures down to freezing.

VARIATION IN THYROID WEIGHT BETWEEN SPECIES

Comparison of "thyroid" weights in different species have been made by Crile and Quiring (1940), Hartman (1946), and Hartman and Brownell (1961). Hartman found no differences between sexes among songbirds in weight of "thyroids", nor between the weights of the "thyroids" of species nesting in the

TABLE 7

Average weight of thyroids of adult birds during the summer, arranged in order of decreasing body weights

Species	Number of birds	Body weight, grams	Thyroid weight, milligrams	Per cent of body weight
Sparrow Hawk *Falco sparverius*	1	113.5	13.3	.0117
Robin	2	80.0	7.9	.0099
Redwinged Blackbird *Agelaius phoeniceus*	1	61.4	5.9	.0096
Yellow-billed Cuckoo *Coccyzus americanus*	1	57.8	7.1	.0123
Wood Thrush *Hylocichla mustelina*	1	52.1	5.7	.0109
Rufous-sided Towhee	8	41.3	2.1	.0051
Catbird	3	39.2	4.7	.0120
Cedar Waxwing *Bombycilla cedrorum*	1	32.4	3.3	.0102
House Sparrow	3	26.3	2.8	.0106
Vesper Sparrow *Pooecetes gramineus*	1	25.2	1.0	.0040
Tufted Titmouse	4*	22.0	1.6	.0073
Song Sparrow	7	20.6	1.5	.0073
White-breasted Nuthatch	9*	19.2	1.4	.0073
Red-eyed Vireo	4	16.2	1.8	.0111
Indigo Bunting *Passerina cyanea*	1	12.9	1.3	.0101
American Goldfinch	3	12.6	1.4	.0111
Field Sparrow	2	11.7	0.9	.0077
Black-capped Chickadee	4	11.1	0.5	.0045
House Wren	6	11.0	0.7	.0064
Chipping Sparrow *Spizella passerina*	1	10.1	0.5	.0050
Black-throated Green Warbler *Dendroica virens*	1	9.6	0.7	.0073
Chestnut-sided Warbler *Dendroica pensylvanica*	1	8.9	0.5	.0056
American Redstart *Setophaga ruticilla*	1	8.2	0.45	.0055
Ruby-throated Hummingbird *Archilochus colubris*	1	2.5	0.2	.0080

*Possibly includes some juveniles.

United States and the same species wintering in Panama. Histological criteria also show little or no significant change in the activity of the thyroids of migrant species between summer and winter (Oakeson and Lilley, 1957). Among the birds in Panama, there was a straight line relation between increasing "thyroid" weight and body weight.

Because of seasonal variation in permanent resident species, perhaps the summer season, when the thyroids are relatively inactive, is the best time of the year for comparing their weights in different species. Data on adults of 24 species were obtained for this purpose, varying over 45X in body weight (table 7). In 13 of 18 species, where comparisons are possible, the "thyroid" weights given by Hartman are heavier than those weighed by us; in four species they are nearly the same; in one species (Redwinged Blackbird) the weight given by Hartman is less, but it is for birds weighing considerably less than our one bird. Actually, the weights given by Hartman (personal communication) include the parathyroids along with the thyroids while our weights are for only the thyroids.

A significant (<0.05) straight-line regression occurs between thyroid and body weights with a coefficient of $+0.116$. The equation is $\hat{Y}=2.8+0.116$ $(X-29.4)$, where $\hat{Y}$ is the weight of the thyroids in milligrams and X is the body weight in grams. This means that birds weighing 10 g should have thyroids weighing 0.0055 per cent of their body weight, those weighing 25 g, 0.009 per cent; 50 g, 0.010 per cent; and 100 g, 0.011 per cent. In other words, larger birds have larger thyroids, not only actually, but also relative to their body weights.

This relation is contrary to expectations, since small birds, in proportion to body weight, have higher rates of metabolism. The relatively smaller weights of the thyroids in the smaller species may mean that even in the summer months the thyroids of the smaller species are more active than the thyroids of the larger species and hence have less colloid in storage. It is of interest in this connection that a straight line drawn by eye to best fit the data in figure 2 of Hartman's 1961 paper shows that smaller birds have relatively heavier thyroids and parathyroids taken together.

DISCUSSION

Within any single species, the weight and volume of the thyroids are useful indices of thyroid activity, since weight and volume are positively correlated with the size of the follicle, which in turn is inversely correlated with the height of the epithelial cells lining the follicles. These criteria for thyroid activity must, however, be employed with caution. Repeated injections of thyrotropic hormone over a long period, maintaining standard metabolism and thyroid activity at a high level, will induce hyperplasia and considerable enlargement of the thyroid gland (Miller, 1939). A long continuous period of cold stress may also bring an increase in the size of the thyroid (Hoffman and Schaffner, 1950). The inverse relation between the size and activity of the gland may hold only for moderate fluctuations of temperature such as occur under natural outdoor conditions to which the species is functionally adapted. Excessively long-continued periods of cold stress may at first bring a decrease in size of the thyroid as the stored colloid is depleted, then a hypertrophy, finally exhaustion and atrophy of the follicles (Landauer and Aberle, 1935). Inadequate iodine available in the diet may bring compensatory overgrowth of the thyroid, such as occurs with goiter in man. In young animals, the thyroid increases in size with growth irrespective of activity. Likewise, in comparing the thyroid size of different species, larger species obviously have larger thyroids without the size being an index of degree of activity.

With the criteria for thyroid activity used in this paper, there is little doubt but that the thyroid is more active during the late autumn and winter than during late spring and summer months in the Cleveland region with its pronounced seasonal change in temperature. During the autumn, environmental temperatures become progressively lower; each cold wave is more severe and lasts a longer time. It may well be that the dropping temperatures, along with the shortening photoperiods which put the bird under stress of finding and digesting more food in shorter and shorter periods, stimulate the thyroid to increased secretory activity, whereas, in the spring, the rising temperatures and increasing photoperiods do not so affect the thyroid, although the average temperatures may be the same. In the autumn, the bird is changing from summer to winter acclimatization; in the spring, it is changing from winter to summer acclimatization.

In birds, the adjustment in thyroid activity appears to be slower and more gradual than in at least some mammals. Domestic fowl, when experimentally exposed to 4.4°C, after being at 13° to 24°C, had their thyroids show very little increase in secretory activity during the first 10 days. Five birds reached a maximum secretory rate within 32 days, 14 birds between 32 and 54 days, 2 birds between 85 and 112 days, while 2 birds continued a slow increase for 190 days (Stahl et al., 1961). In Missouri, the secretory rate of the thyroids in winter is about twice what it is in summer (Stahl and Turner, 1961). Apparently the thyroid is involved more in long-time acclimatization to progressive trends in temperature than in the regulatory mechanism concerned with day-to-day or hour-to-hour fluctuations in temperature.

It appears very probable, therefore, that the greater ability of House Sparrows to mobilize reserve energy in the body during starvation, to attain higher levels of metabolism (Miller, 1939), and to tolerate considerably lower environmental temperatures, all of which are evident during the winter, is associated with a higher level of thyroid activity, and inferentially also of the anterior pituitary. Doubtlessly other factors are also involved, however, and much more needs to be done before we can understand the intermediary mechanism whereby seasonal changes in the environment produce the effects that they do.

CONCLUSIONS

1. In the thyroids of House Sparrows, high epithelial cells occur principally in follicles of small size, and low epithelial cells in follicles of large size. The regression line has the equation $\hat{Y}=6.1-0.074\ (X-24.2)$, where $\hat{Y}$ is cell height and X is the inside diameter of the follicles, both in microns.
2. The diameters of the follicles average smaller in the winter than in the summer in several species of birds. In the House Sparrow, the diameters of the follicles in the autumn are similar to their diameters in the winter, while in the spring, the diameters of the follicles are similar to what they are in the summer.
3. Calculated volumes of thyroids in the House Sparrow are smaller in juveniles than in adults in the summer, and are smaller in adult birds during the autumn and winter than in adult birds during the spring and summer.
4. No consistent difference between sexes in the weight of the thyroids could be demonstrated.
5. The thyroids in nestling House Wrens appear to reach the weight found in adult birds when they are 7 days old. From fourteen days of age through the juvenile stage, there may be a decrease in size of the thyroids, both absolute and relative, but this could not be substantiated statistically. The weights of thyroids in juvenile birds of various other species are generally less than in adult birds.
6. The weights of the thyroids in several species of birds average less in winter than in summer.
7. Large species of birds have larger thyroids in the summer, both absolute and relative to body weight, than do small species. The regression line has the equation: $\hat{Y}=2.8+0.116\ (X-29.4)$, when $\hat{Y}$ is the weight of the thyroids in milligrams and X is the body weight in grams.
8. Intraspecific variations in the weight or volume of whole thyroids is a use-

ful index of inverse variations in thyroid activity of wild birds in their normal environments.

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