SEASONAL VARIATION IN THE ACTIVITY OF THE THYROID GLAND OF YEARLING BROWN TROUT *SALMO TRUTTA* LINN.

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(*Received* 12 *September* 1958)

(With Plate 3)

INTRODUCTION

In a previous paper (Swift 1955) the seasonal variation in the activity of the thyroid of 3-year-old brown trout, determined by the rate of loss of radio-iodine from the gland, was described. It was noted that this cycle of activity differed from that described in yearling trout by Smith (1956). Smith using histological criteria found no evidence of a summer activity peak, whereas the radio-iodine technique showed that this was the period of maximum glandular activity in the older fish. It was felt important to find out the reason for this discrepancy which could have arisen either as a result of the age difference between the two lots of fish examined, or because the summer activity was not manifest in the histological appearance of the gland. The results reported in this paper are from a histological and radio-iodine examination of the thyroids of samples of fish from one population or yearling trout.

METHODS

A population of yearling trout were reserved for this work in a large stewpond at the experimental hatchery of the Freshwater Biological Association; they received the same treatment as normal hatchery stock, and at sampling time random samples of thirty-two fish were taken for examination.

RADIO IODINE

The technique used for the determination of the glandular activity with radio-iodine was exactly the same as that previously described (Swift, 1955). After injection with isotope solution the activity of the thyroid area was determined at intervals of 24, 48, 72 and 96 hr. The fish, anaesthetized with tricaine methano sulphonate were allowed to recover in running water after each examination and returned to the hatchery. The regression coefficient for the slope of the iodine loss time curve over the period of examination was taken as the index of activity of the gland, all counts being corrected for background count and the natural decay of the isotope.

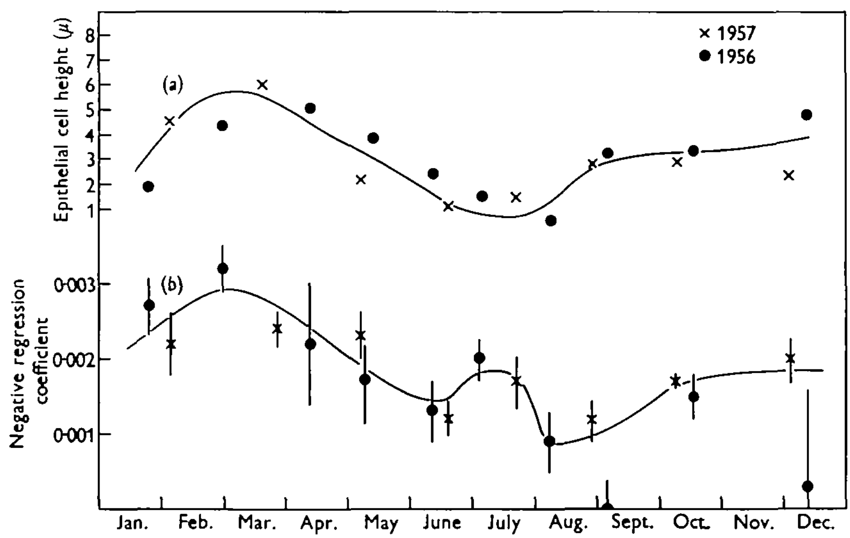
From the sample of fish, twenty were examined with radio-iodine, and the remaining twelve were used for histological examination.

HISTOLOGY

The fish were killed by a blow on the head and the thyroid area was immediately excised and fixed in corrosive formaldehyde. The fixed tissue was dehydrated in diethylene dioxide and embedded in ester wax. Sections 10 μ thick were cut and stained in Delafield's haematoxylin and eosin Y. The sections were examined at a magnification of $\times 500$ and the epithelial cell height of thirty follicles from each fish was measured. Thirty follicles were examined, as this was found by experience to be the largest number of follicles visible in one section of the thyroid for all the fish in the period under review.

The temperature of the water in which the fish were living was taken evening and morning and the results expressed as an average, calculated to each sampling time.

This work was first carried out during 1956, and was then repeated during 1957 using a fresh population of yearling fish.



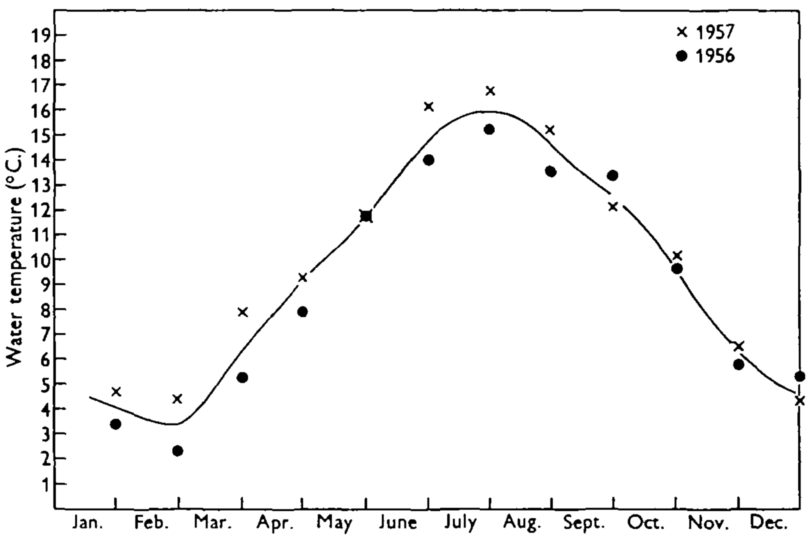
Text-fig. 1 *a*. Seasonal variations in the thyroid epithelial cell heights during 1956 and 1957. Each point represents the mean height of thirty follicles from twelve fish. In each case twice the standard deviation from the mean is too small to show (< 3 %).

Text-fig. 1 *b*. Seasonal variations in the thyroid gland activity during 1956 and 1957. The glandular activity is expressed by the regression coefficient for the iodine loss/time curve. (The height of the vertical lines $= 2 \times \pm$ the standard error of the mean.

RESULTS

The mean epithelial cell height for each batch of fish is shown in Text-fig. 1 *a*. The results for both years 1956 and 1957 are so similar that they have been combined on one graph and one trend curve drawn through the points. The picture of the seasonal variations in glandular activity agrees with the findings of Smith and shows a maximum activity in February and March, then a slow decline to July, after which the activity after an initial sharp rise during August slowly increases throughout the autumn and winter.

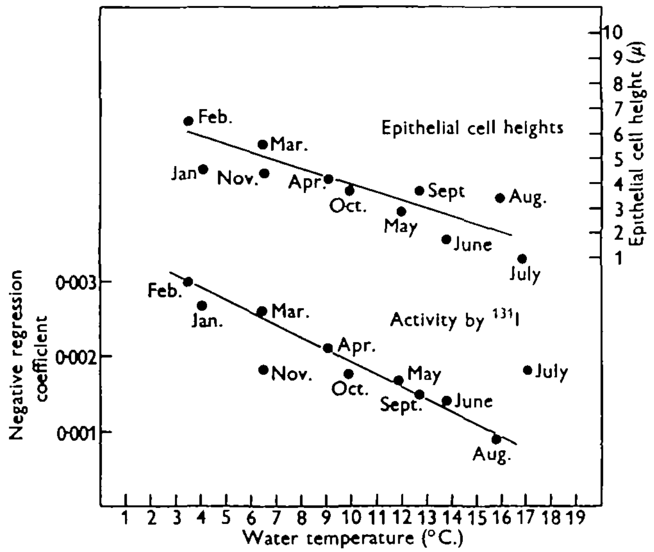
The results recorded with the radio-iodine technique are shown in Text-fig. 1*b*; again the results were so similar for the 2 years that they are combined in the one graph. This method confirms that the peak thyroid activity occurs during February declining to June, but then demonstrates that, as was found in the older fish (Swift, 1955), the activity of the gland rises sharply during June, falling again during July to reach its lowest level in August, after which it slowly rises during the autumn and winter.



Text-fig. 2. Seasonal variation of the temperature of the water in which fish were living. Each point represents the mean of twice daily readings over the preceding period.

DISCUSSION

In view of the recent detailed and excellent review of the literature on the teleost thyroid by Pickford (Pickford & Atz, 1957) and also that by Hoar (1957), it is not felt necessary to review here the many ideas on the function of the thyroid in teleosts. Periods of high activity have been indicated to occur at the same time as, among others, the following processes; larval morphogenesis, the metamorphosis of eels and flatfish, smoltification of salmon, and sexual maturation. After reviewing all the available data on the subject Pickford concludes that it appears increasingly probable in spite of evidences to the contrary, that the thyroid plays some role in the respiratory metabolism in teleosts. Huxley (1929) first suggested that the thyroid gland in poikilothermic animals may in some way act as a temperature-compensating mechanism, having a greater activity at lower environmental temperatures than at high ones. A comparison of the water temperature curve for 1956 and 1957 (shown combined in Text-fig. 2) and the thyroid activity curve (Text-figs. 1*a*, 1*b*) suggested that, with the exception of the June–July peak, the activity of the gland was inversely proportional to the water temperature. This is clearly demonstrated in Text-fig. 3, where the glandular activity is shown plotted against the water temperature.



Text-fig. 3. The glandular activity measured by the epithelial cell height and radio-iodine plotted against the water temperature. The readings for glandular activity are taken from the trend curves drawn in Figs. 1 *a* and *b*.

This relationship of glandular activity and water temperature is interpreted as further evidence that the basic function of the thyroid is concerned in the control of the animal's metabolism, in this case in such a fashion as to compensate for changes in the environmental temperature. Thus the release of thyrotropic hormone by the pituitary would seem to be influenced by the environmental temperature. Consideration of the summer activity peak suggests, however, that the release of thyrotrophic hormone is also affected by other stimuli—always, it would seem, when the response of the animal to these stimuli requires an increase in metabolism in whole or part. If this is indeed the case it would explain the various diverse occasions when an increase in thyroid activity has been indicated to occur. In this connexion it is perhaps illuminating to compare the results described in this paper with those previously reported (Swift, 1955). The activity of the gland of the maturing fish during the period of gonad maturation is much greater than that shown by the immature yearling fish at the same season, indicating an increase in thyroid activity at the time of gonad maturation. However, this does not account for the increase in activity in the yearling immature fish. It is interesting to note that it occurred around the time of the longest day, but until more is known about the effect of the gland on the metabolism, and also about the seasonal variation in glandular activity which presumably occurs in other species—in particular, species which mature at a different season than the brown trout—it is difficult to suggest a reason for this peak.

It is immediately obvious from Text-figs. 1 *a*, *b* that an estimation of thyroid gland activity based solely on the histological criteria of epithelial cell height could be misleading. It is doubtful whether, in fact, the summer activity peak is demonstrated by this method, although in Text-fig. 1 *a* a slight rise in epithelial cell height at this period could be indicated, but could also be the result of the curves for the 2 years being slightly out of phase at this point. However, when the thyroid sections are examined in the light of the iodine turnover rates additional information becomes apparent. The photomicrographs shown in Pl. 3, figs. 1–3, show the appearance of the gland at different times of the year. Pl. 3, fig. 1 is a section of a March gland and shows a typically spring active thyroid; by May the epithelium has become flatter and a great hyperplasia has taken place. Pl. 3, fig. 2 shows such a hyperplastic gland. In July, when the gland has again been shown to be active, the epithelium is still flat but the gland is highly vascular. Pl. 3, fig. 3 shows such a gland in which some of the follicles are ruptured and invaded by blood cells. This follicle rupturing has been noted before (Bargmann, 1939) and it has been suggested that this is one way in which the stored hormone is released into the blood stream.

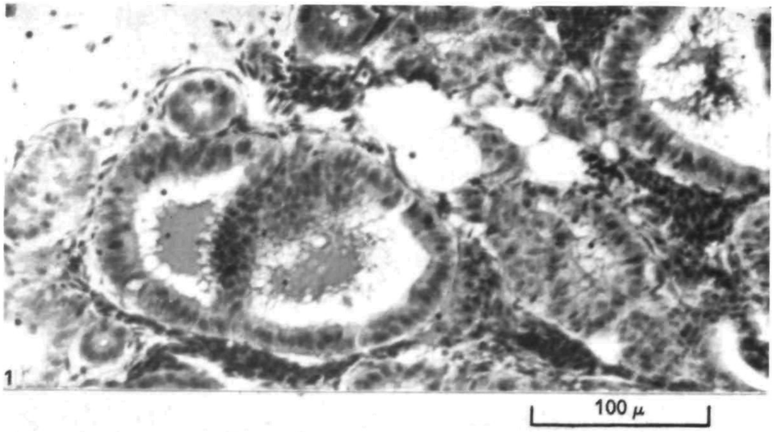
Consideration of these changes in the histological appearance, and the actual activity of the gland, has led to the suggestion that the rate of change of the level of thyrotropic hormone in the blood of the fish determines the mode of response of the thyroid to this hormone. Thus slow changes in the level, as it is supposed occur seasonally with changing water temperature, are responded to by a change in epithelial cell height, indicating a change in glandular activity. However, if the change in thyrotropic hormone level is rapid, as supposedly it is in July, then the stored hormone in the gland is released, the epithelial cells increasing in height later in August when their heightened activity replenishes the stores of hormone released in July. It is not suggested that this is a full account of the seasonal changes in behaviour of the thyroid—it does not account, for instance, for the hyperplasia found in May—but it is hoped that these ideas may stimulate further work on these lines especially with fish which spawn at times other than does the brown trout.

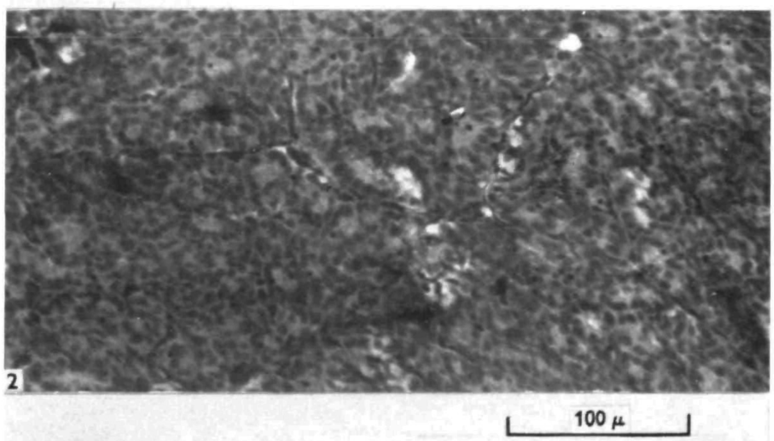
In conclusion it is perhaps worth noting that a study which would be very valuable—and which, as far as is known has never been made, presumably owing to the analytic difficulties involved—would be a survey of the iodine content of the water in which fish were living in conjunction with a survey of their thyroid activity. It has been shown that iodine deficiency will stimulate the thyroid and it may be there is a seasonal fluctuation of the iodine content in natural waters.

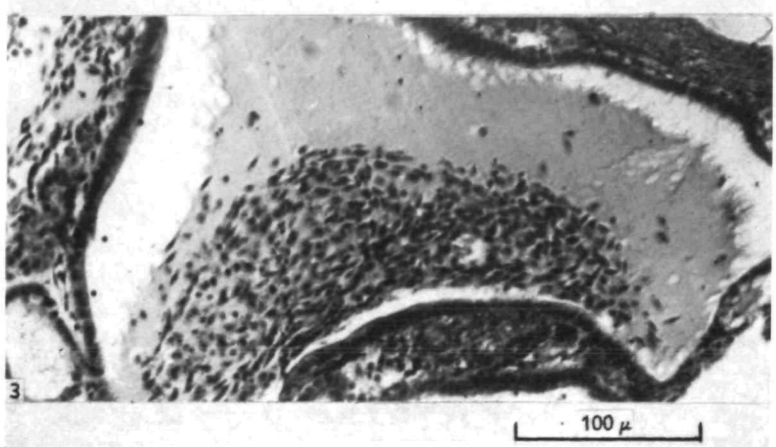
SUMMARY

1. Seasonal variations in the activity of the thyroid gland in yearling brown trout were measured by two methods; first, by the changes in thyroid epithelial cell height and, secondly, by the rate of loss of radio-iodine from the gland.

2. Peak thyroid activity was found to occur in spring with a second peak demonstrable by the radio-iodine technique in mid-summer.







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3. With the exception of this short burst of activity in July, the activity of the thyroid was found to be inversely proportional to the water temperature.

4. It is suggested that the thyroid is concerned in a temperature-compensating mechanism.

5. It is suggested that the rate of change of the thyrotropic hormone level in the blood determines the mode of response of the gland.

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EXPLANATION OF PLATE

Fig. 1. Follicles from an active March gland.

Fig. 2. An extreme example of a hyperplastic May gland.

Fig. 3. A large follicle with low epitheliam invaded by blood corpuscles, a July gland.