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## ON THE MECHANISM OF THE APPEARANCE OF THE SCALE STRUCTURE

### III. On the Regeneration of the Scales of the Crucian Carp, *Carassius carassius* (L.) when They are reared with the Different Food

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#### Introduction

Heretofore, all questions into the circumstance of the scale structure have dealt with the idea that the intervals between circuli is controlled by the growth of fish or the quality of food. In his latest work, R. Ichikawa (1953) stated that the absorption of the scale occurs under conditions of mal-nutrition. His opinion is based on histological observations on four individuals of the carp, *Cyprinus carpio*, reared under the condition of starvation during nine or ten months. The present author undertook to examine the relation of nutrition to the growth of scale by the regeneration of scale under the conditions of difference in food. It is the author's opinion that regeneration was not always affected by the nutrition. Furthermore, so far as the present material is concerned the absorption of the bony layer under starvation conditions was not recognized at all.

#### Observation

Several Crucian carp, *Carassius carassius* (L.) two years old, ranging from 2.4 to 4.1 cm in body length were narcotized with urethan, and their right three scales on a scale-row just above the lateral line at the posterior part of the foot of a perpendicular from the anterior end of the dorsal fin to the lateral line were removed. Then, they were placed into three normal fresh water tanks, and were fed respectively with crumbs, *Limnodrilus* and non-food during about 40 days in the open at the Institute of the Hokkaido University at Sapporo. The specimens from each tank were examined occasionally. The degree of nourishment was shown by the relation of the body length to the body depth or the body breadth. The progress of regeneration was deduced by the degree of development of the scale structure, additionally, the regenerated scale was sectioned by the paraffin method for histological examination.

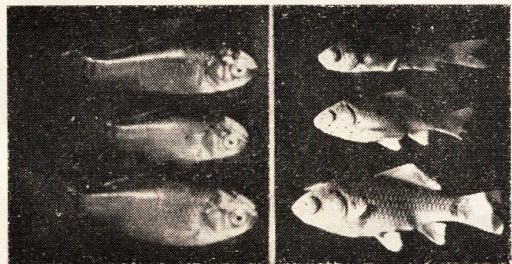


Fig. 1. Specimens from each group at three weeks (June 3rd, 1953) and on the 41st day (June 23rd, '53) after the operation. The former (left) shows the slight difference of the fatness and the complete regeneration of scales, and the difference of the fatness in the latter (right) is clear; top to bottom, a non-food-, a crumbs- and a *Limnodrilus*-group-fish.



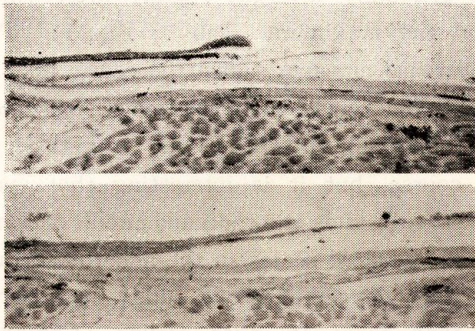


Fig. 2. The fibrous layer of the regenerated scale; that of the good-nutrition fish is thicker than that in the mal-nutrition (top).

The ratio of body depth to body length was the largest in the *Limnodrilus*-group and smallest in the non-food group. The emaciation in the non-food group resulted from the fact that the body length is almost not affected while the body depth became less. On the other hand, the scales did not shrink, accordingly, the scales overlapped one another in greater degree in the body-depth-axis than in the body-length-axis (Figs. 4, 5).

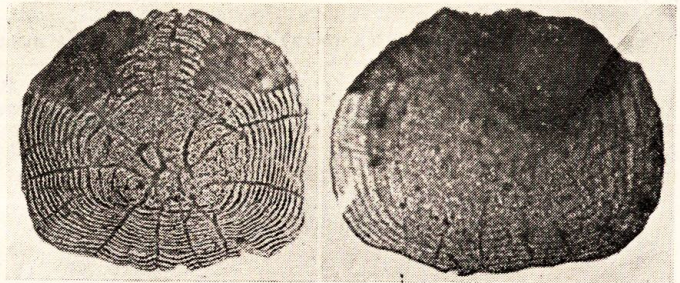


Fig. 3. Regenerated scale on the 41st day after the operation from a non-food- and a *Limnodrilus*-group-fish, showing the former (left) to be rather clearer than the latter (right) in scale structure.

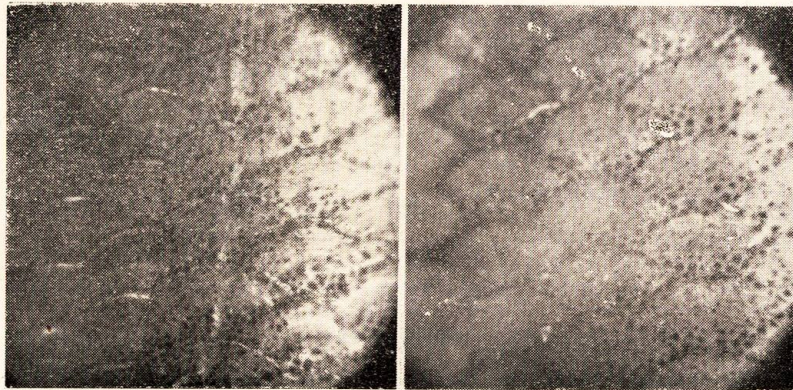


Fig. 4. Skin of the mal- (left) and the good-nutrition fish (right), showing the stronger overlapping of scales of the mal-nutrition as compared with that of the good-nutrition-fish.

Within three weeks after the operation, the scales of all fishes were so regenerated that the scar was not apparently recognizable. A slight difference in fatness appeared between the groups (Fig. 1, Table. 1), but the structure of the regenerated scales in three groups was nearly the same; only three or five circuli appear in all the regenerated scales at their anterior part, but the growth of the fibrous layer in the good-nutrition group was somewhat better than in the mal-nutrition group (Fig. 2).

The difference of fatness in each group gradually diverged rapidly after three weeks, and by about a month it attained the maximum (Tab. 1, Fig. 1). The emaciation of the non-food group did not increase any more until the death on the fortieth day after the operation. At the last the regeneration of scales presented

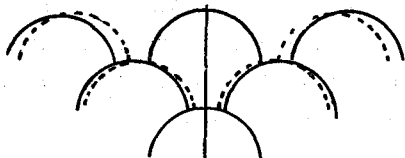


Fig. 5. A diagrammatic figure showing the transfer of scales caused by the fatness of fish.

individual differences as a matter of course, but it is interesting that such structures as the radii and circuli of some regenerated scales in the non-food group were developed more surely in general than those of other groups (Compare two scales of Fig. 3).

Table 1. Measurements of specimens in three groups. The emaciation in the non-food group and the growth in the other groups attains maximum in about one month after the operation.

	Date started	Date examined								
	May 12, '53	Jun. 3, '53(3 weeks)			Jun. 13, '53(a month)			Jun. 23, '53(41 days)		
	Body length (cm)	Body length	Body depth (to body length)	Body breadth (to body length)	Body length	Body depth (to body length)	Body breadth (to body length)	Body length	Body depth (to body length)	Body breadth (to body length)
Non-food group	3.60	3.54	1.10 (0.310)	0.51 (0.144)	3.18	0.88 (0.277)	0.51 (0.160)	2.38	0.66 (0.279)	0.39 (0.164)
	3.20									
	3.30									
	2.40									
	2.60									
Crumbs-group	2.70	2.85	0.97 (0.340)	0.55 (0.193)	3.10	1.20 (0.387)	0.61 (0.197)	4.24	1.64 (0.387)	0.82 (0.193)
	2.70									
	3.00									
Limodritus-group	3.85	3.95	1.41 (1.357)	0.77 (0.195)	4.10	1.59 (0.388)	0.81 (0.198)	3.31	1.28 (0.387)	0.66 (0.199)
	4.00									
	3.10									

### Conclusion

The author reported in the previous paper that the outline of scale is regenerated during a short period (Saito, S. & J. Yamada, 1953). In the present experiment there was found also a scale which in size and form was like the removed one within three weeks. However, in this regenerated scale, the upper bony layer which builds the scale

structure is limited only at the peripheral thin part of the lower fibrous layer regenerated completely. This fact shows that the fibrous layer has a close connection with the whole inside of the scale sac while the bony layer has connection with only its periphery. The providing of good-nutrition results in the high growth of the fish, and the growth of the body must be surely accompanied with the growth of the scale sac, hence it is presumable that the growth of the fibrous plate of the scale is influenced by the nutrition. The present result accords with this presumption in respect to the fibrous plate, while the constitution of the bony layer is seen to be independent of the nutrition. It is unreasonable to imagine that a simple mechanical cause such as the destruction of tissue of the scale sac by the removing of the scale has any effects on the regeneration during so long a period as 41 days.

Now, the author is beset by misgivings that the mechanism of the appearance of scale structure may not be directly connected with nutrition.

#### Literature cited

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