

is usually found entering into the terminal of the groove (Figs. 5 and 7). An electron microscope observation of a tangential section of this terminal region revealed the osteoid separated bilaterally by intervening cells (Figs. 8 and 9). The intracellular characteristics of these cells are almost same as those of the round marginal cells except that they show an occasional occurrence of fine cytoplasmic filaments and some vacuoles. Another section through just the inner region shows a rectangular cell tightly fitted to the groove (Fig. 10). At the bottom of the groove is found a thin layer of osteoid in which some coarse collagen fibers measuring 600 Å in diameter are randomly dispersed. It is structurally different from the ordinary osteoid that has no such thick collagen fibers. Furthermore, the bottom osteoid seems to be never calcified even after the bilateral osteoid has completely calcified. Along the side walls of the groove are noted fine collagen fibers forming a brush-border-like structure between the surface of the groove cell.

### Cells associated with the fibrillary plate

The fibrillary plate appears at first as a thin fibrous lamina under the calcifying osseous layer (Fig. 11). The absence of such fibrous structure under the osteoid zone suggests that its formation is preceded by the growth of the osteoid. The thickening of the fibrillary plate seems to be brought about by the sequential piling of about 1  $\mu$  thick laminae in which the direction of the collagen fibers is altered from one to another (Fig. 12). The newly formed fibers in direct contact with the underlying cells are about 300 Å in diameter and seem to grow thicker to about 600 Å as they are organized into a fibrous lamina. An amorphous substance of low density is found to fill the interfibrillar spaces.

There are usually two cell layers lining the fibrillary plate. The cells of the inner layer show the most developed GER among other scale-associating cells suggesting their high collagen producing activity. Well developed Golgi complexes with large vacuoles are

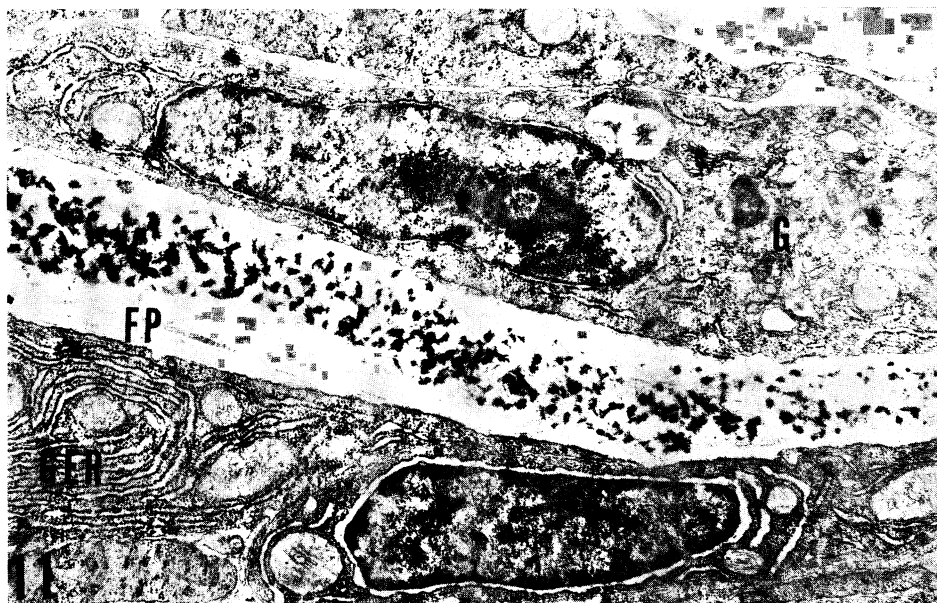


Fig. 11. Fibrillary plate (FP) appeared as a thin fibrous lamina under the calcifying osseous layer. Note that the deposition of collagen fibers is paralleled with an extension of GER in a cell of the lower left. G, Golgi complex.  $\times 12,000$ .



Fig. 12. Piling of fibrous laminae in the fibrillary plate (FP) and associated cells. Directions of collagen fibers are altered in the laminae one after another. There are two cell layers lining the undersurface of the fibrillary plate. Cells of the inner layer show extensively developed GER, in contrast to poorly developed cell organelles in those of the outer layer. A small eccyctic vesicle (arrow) is also observed. D, dermis; FC, fibrogenic cell.  $\times 15,600$ .

Fig. 13. Large granules (LG) surrounded by a single membrane and a cluster of fine cytoplasmic filaments (arrow) in the apical cytoplasm of an inner fibrogenic cell.  $\times 56,000$ .

often noted close to their nuclei. The secretion surface is rather smooth, but some small eccytotic vesicles apparently liberating their contents are occasionally observed (Fig. 12). Large round granules bounded by a single membrane and clusters of fine cytoplasmic filaments occur occasionally in their apical cytoplasm (Fig. 13). The granules, measuring up to  $1\mu$  in diameter, show a dense homogeneous substance containing some vacuoles and vesicles. The nature of these granules is unknown, but their appearance reminds us of lysosomal bodies. Also, the presence of some desmosomes may be notable for these non-epithelial fibrogenic cells (Fig. 12). Poorly developed organelles in cells of the outer layer well suggest that these cells are metabolically less active (Fig. 12). They are supposed to be activated for further growth of the fibrillary plate after the disintegration of the inner cells.

### Discussion

Cells being concerned in the scale growth may be primarily divided into two groups, one forming the osseous layer and the other the fibrillary plate. Those belonging to the former group can be classified into three types according to their topography, size and shape, and fine structure: (1) small round cells surrounding the marginal osteoid zone having relatively large nuclei and less developed GER and Golgi complexes among other scale-forming cells; (2) large flattened cells covering the calcifying osseous layer including those associated with the growing ridges, in which GER and Golgi complexes are considerably developed as compared with those of the marginal cells; (3) cells found in the terminal of the groove having a close similarity in structure with the marginal round cells.

It is evident that the marginal cells develop into the flattened cells forming the osteoid matrix (Maekawa and Yamada, 1970; Waterman, 1970; Yamada, 1971). Their osteo-

genic nature is consistent with their fine structural feature that was reported in bone tissues (Dudley and Spiro, 1961; Robinson and Cameron, 1964; McLean and Urist, 1968). Therefore, they may be referred to as "osteoblasts" considering their functional as well as morphological characteristics.

It was recently reported on the chum salmon scale that the ridge in section appears to be laid down in the intercellular space when an upper osteogenic cell was obliquely overlaid by the outer adjacent one in the course of the flattening of those cells (Yamada, 1971). This agrees with the present study of the goldfish scale. Yamada has also suggested that the liberation of the ridge material may be mainly attributable to the activity of the outer cell while the inner cell helps accumulate or block the levelling of the material evidenced by the faster degeneration of the outer cell. There may be another possibility, however, that both the inner and the outer cells equally participate in the ridge formation, because, in the goldfish scale, a good difference in the fine structure could hardly be observed between these cells. Leaving the nucleus with a small amount of remaining cytoplasm at the inner face of the ridge, the inner cell seems to have changed its nature from osteogenic to osteocytic possibly caused by a protective effect of the fully grown ridge.

The absence of the osteoid matrix at the terminal of the extending groove has been shown also by Waterman (1970). It is unlikely, therefore, that the groove extends in resorbing the osteoid matrix by the osteolytic activity of the cells in the groove as was suggested by an earlier light microscope study (Yamada, 1961). That the fine structure of the cells lying in the terminal of the groove was almost indistinguishable from that of the round cells of the scale margin suggests that they possibly have originated from the marginal cells and remained in the groove without forming actively any osteoid material. Accordingly, a possible explanation for the

extension of the groove may be that the cells in question are blocked to produce osseous materials and, consequently, prevent accumulation of the osteoid matrix at their existing site. A mutual conversion could occur between the osteogenic cells and the groove cells because in the goldfish scales some grooves are often observed to be interrupted or to start newly on the way from the focus to the margin (Yamada, 1961).

The non-calcifiable nature of a thin osteoid-like layer lining the bottom wall of the groove revealed its structural difference from both the true osteoid and the fibrillary lamina. The 600 Å collagen fibers which are not found in the ordinary osteoid are dispersed randomly in striking contrast with those densely packed in the fibrillary plate. The specific feature of the groove seems to support the idea concerning the possible role of the groove that it would give flexibility to the scale (Neave, 1940; Wallin, 1957; Yamada, 1961). Dietrich (1953) considered that the groove functions in the transport of the cells as she also observed cells in it. Since the nature of the cells found in the groove is as discussed above, it is difficult to regard the groove as a canal for transport of the cells.

The fibrillary plate of the goldfish scale is composed of several laminae distinguished by the alternation in the direction of collagen fibers of 600 Å as has been reported in other fish scales (Maekawa and Yamada, 1970; Waterman, 1970; Yamada, 1971). The cells beneath the fibrillary plate are identified as "fibroblasts" from their active collagen-producing ability which is shown by the characteristically developed GER and Golgi areas (Fitton-Jackson, 1964; Ross, 1968). These cells seem to be responsible for the formation of, at least, more than one lamina because no degenerative phase of the cells is observed even after the completion of one lamina.

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#### キンギヨ鱗の生長に關与する細胞の形態的特徴

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キンギヨ鱗の生長にあずかる細胞を光顕・電顕觀察により四種類に區別し、それぞれの形態的特徴と機能につき考察し、さらに条溝部位の微細構造に注目した。

各細胞は、それぞれ鱗の骨質層、隆起線、条溝、およ

び線維性板の各構造の生長に関係している。すなわち、(1) 骨質層生長縁の類骨帯を囲む小型細胞、(2) 骨質層石灰化部位に接する大型の扁平細胞、(3) 条溝内に存在し条溝の伸長に資する(1)に似た細胞、および(4) 鱗下面の線維性板に接着しその線維層板を産生する細胞の四種である。(1)と(2)の細胞は、ともに骨基質の生産に関与する形態的にも骨芽細胞と対比し得る構造を示す細胞で、(1)から(2)に移行する過程で隆起線の形成をもたらす。条溝内の細胞は(1)の細胞に由来し、骨基質の

生産を抑止された状態下に置かれたもののように思われる。線維性板産生細胞は線維芽細胞としての特徴を示し、同一細胞が一以上の線維層板の形成にあずかるようである。

条溝底面は骨質層とも線維性板とも異なる、石灰化しない特殊な微細構造を示し、このことから条溝は、鱗に柔軟性を与える一種の関節様構造であるとみなされる。  
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