

Fig. 23. Perinuclear region of the young fibroblast. The lamellar endoplasmic reticula (ER) is separating a number of desmosomes (D) and septate desmosomes (sD), and strong interdigititation (*) is present in the region of free desmosomes. A moderated fibrous dense body (arrow) and masses of free ribosomes (R) can also be seen in the perinuclear portion. Mf, microfilament; N, nucleus.

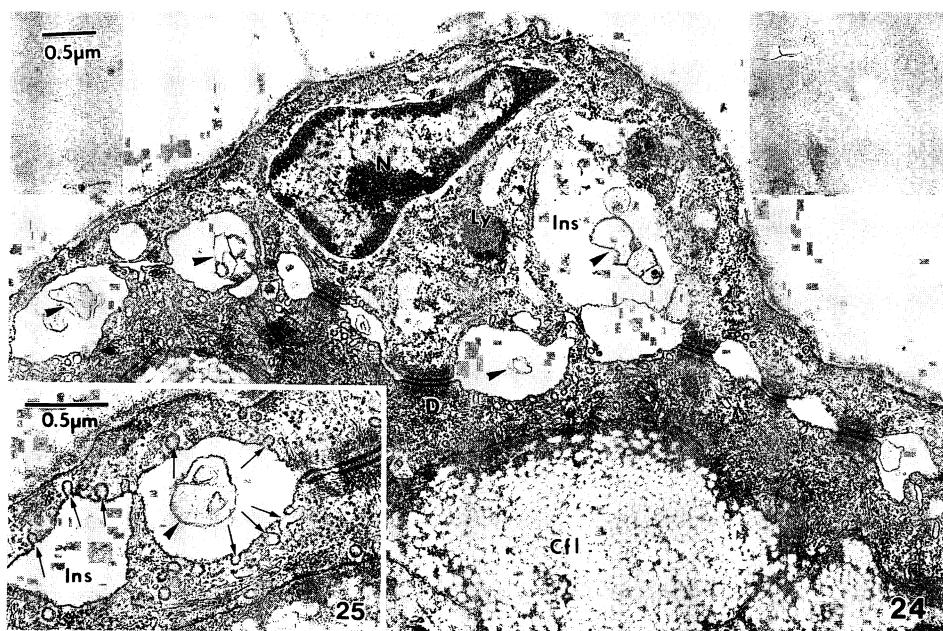
region of the dermal layer (Fig. 21), while myelinated nerve fibers are aligned under blood capillaries (Fig. 27).

Discussion

Previously, light microscope studies have been made on the intraepithelial blood capillaries of the respiratory organs of *P. vulgaris* and *P. modestus* (Schöttle, 1932; Maekawa et al., 1968). The ultrastructure of the skin of *P. modestus* was still unknown, although it provides a unique model for studies on terrestrial adaptation in amphibious animals. Harms (1935) suggested that the mudskipper's blood vessels were well developed in the epithelium of the dorsal skin, and Maekawa et al. (1968) reported that the blood capillaries of *P. modestus* were completely lacking in the ventral region, in which well-developed scales are distributed. In the present study, however, several blood

capillaries were detected in the outermost part of the ventral epidermis, though large scales penetrated deeply into the middle epidermal layer. Flask-shaped cells were also observed in the outermost part of the epidermis. Whitear (1965) presumed that a similar structure detected in the epidermis of *Phoxinus laevis* was a sensory cell, but this remains to be confirmed.

Concerning the epidermis, intraepithelial blood capillaries are an extraordinary occurrence (Maekawa et al., 1968). On the other hand, the intestinal epithelium in the loaches, *Misgurnus angullicaudatus*, *Cobitis fossilis* and *C. biwae* (Erman, 1808; Edinger, 1877; Lorent, 1878; Lupu, 1908; Suzuki et al., 1963; Maekawa et al., 1968), the skin of *P. modestus*, *P. vulgaris* and *Anguilla japonica* (Schöttle, 1932; Maekawa et al., 1968), the air sac of *Monopterus cuchia* (Munshi et al., 1989) and the labyrinth of *Channa maculata* and *Anabas* spp. (Maekawa et al., 1968) are well known. Thus, the intraepithelial blood capillaries are an elabo-



Figs. 24, 25. The fibroblast during its senescent phase. Residual bodies (arrow heads) and endocytosis or exocytosis (arrows) are seen in the intercellular spaces (InS). Cfl, collagenous lamella of the dermis; D, desmosome; Ly lysosomal dense body; N, nucleus.

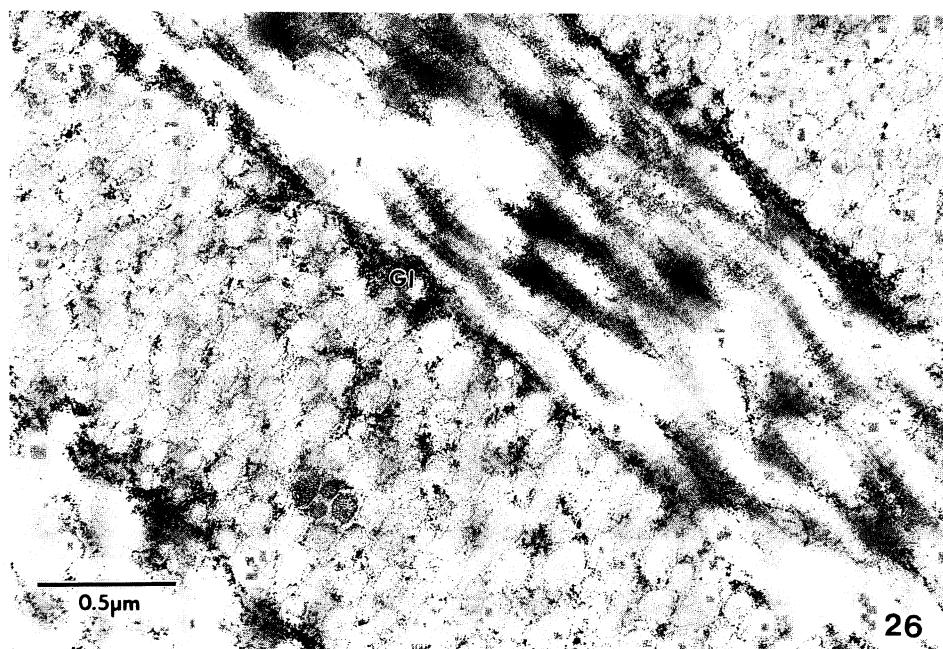


Fig. 26. Bundles of collagen fibrils in the dermis. Gl, glycogen granule.

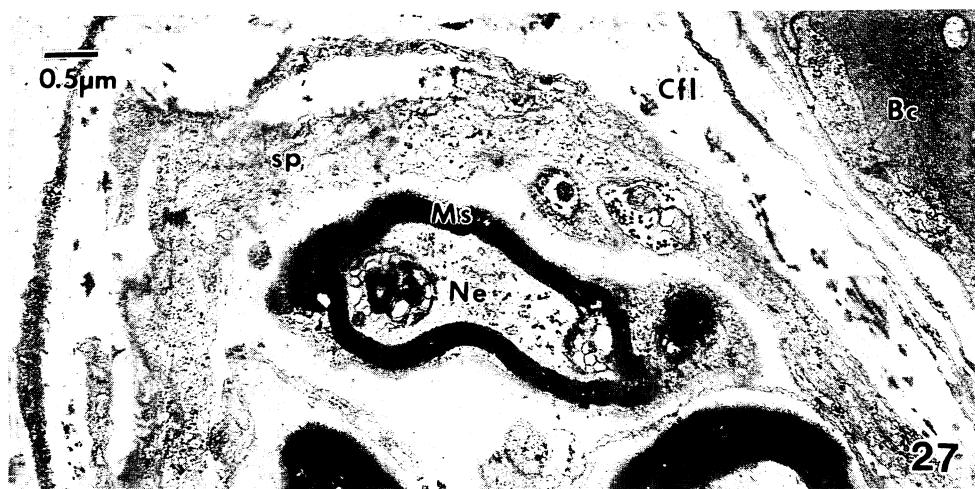


Fig. 27. Myelinated nerve fibers (Ne) lined-up under the blood capillary (Bc) are seen in the collagenous lamella of the dermis (Cfl). Ms, myelin sheath; sp, sarcoplasm.

rate system for air-breathing. Similarly, intraepithelial blood capillaries were demonstrated in *Lefua echigonia*, *Rhinogobius brunneus* and *Tridentiger obscurus* (Suzuki and Hiraki, 1991). Tamura et al. (1976) reported that the rate of oxygen uptake of *P. modestus* via the skin was 48% in water. From these facts, it is assumed that air-breathing, or gas exchange, through the skin of amphibious fishes in water is an important device.

Within the epidermis of various vertebrates there are two developmental pathways, one related to keratinization and the other to mucogenesis. This duality in developmental potential is related to environmental adaptation, i.e., keratinizing cell types occur predominantly in terrestrial animals, whereas mucous-producing cells are found in amphibious and aquatic forms (Henrikson and Matoltsy, 1968). The presence of epidermal mucous cells is one of the basic characteristics of bony fishes, in addition to the occurrence of granular cells (Studnicka, 1906; Rauther, 1907; Bhatti, 1938; Sato, 1967, 1978; Thompson, 1969; Munshi, 1971). However, the epidermis of *P. modestus* is not endowed with either mucous cells or granular cells. On the other hand, the free surface of the epidermis in this species is covered by a fuzzy fibrillar substance. It has been reported that such a fuzzy substance occurs in the outermost layer of the epidermis in numerous fishes (Yamada, 1968; Henrikson and Matoltsy, 1968; Brown and Wellings, 1970; Junqueira et al., 1970; Schliwa, 1975; Mittal et al., 1980). Mittal et al.

(1980) stated that the cuticular layer of *Monopterus cuchia* differed from the secretions of epidermal mucous glands. For *P. modestus*, the fuzzy substance is formed in a cuticle-like layer, but there was no occurrence of keratinization in the integument, as has been described in terrestrial animals. It is surmised that this goby's epidermal surface layer, consisting of Type I cells, fall off more frequently when compared with gobiid fishes which are aquatic dwellers. Moreover, the blood capillaries which are useful for air-breathing are always protected by young Type I cells. The epidermis of bony fishes consists of filament-containing cells (Whitear, 1952, 1977; Henrikson and Matoltsy, 1968; Yamada, 1968; Merrilees, 1974; Aso et al., 1977; etc.). The two types of epidermal cell (Type I and Type II) in *P. modestus* contain a great number of microfilaments. Tamura (1977) conjectured that the enormous vacuole of Type II cells was filled with liquid. The occurrence of such may be questioned, though its nature might be considered useful in reducing desiccation. The special corky architecture of the cell seems to play an important role in thermal insulation and protection against ultraviolet light in relation to terrestrial life. In the ventral skin, the thickness of the epidermis was about twice that elsewhere, and the scales were deeply inserted into the mid-epidermal layer. In addition, this species has well-developed pectoral fins adapted for walking on land. The granules released from the fibroblasts seem to be engaged in the organization of the collagen lamella,

which may be useful in the skipping movement on land. These findings are supported by the adaptive characteristics in relation to an amphibious life style. However, *P. modestus* frequently exhibits turning behavior on land. Ip et al. (1991) suggested that such behavior is an important means of maintaining a moist dorsal surface during terrestrial excursions. Thus, differentiation of this goby's epidermis seems to be still incomplete for adaptation to its terrestrial life.

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トビハゼ表皮の微細構造

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トビハゼ表皮の構造について光顕および電顕を用いて観察した。本種の表皮には、魚類特有の粘液細胞が観察されない。表皮は、扁平単層な表層細胞 (Type I cell), 立方多層の中層細胞 (Type II cell) そして立方単層の基底細胞の3層構造より成る。各層の細胞とも微細纖維を含有する所謂, filament-containing cell であり、Type I と Type II の両細胞は基底細胞から分化することが示唆された。表層細胞の自由表面には微小堤が存在し、この表面は糖衣で覆われて縞模様を呈している。表層細胞は通常、老化状態にあり、最終的には剥離するが、このような状態の細胞下には必ず若い表層細胞が存在し、加えてこの層には若い表層細胞で裏打ちされた毛細血管が分布している。中層細胞の細胞質は殆ど空胞状態で、細胞膜周囲には tonofilament が特異的に集合しており、この纖維で一種の細胞壁を形成している。この細胞は互いに融合することで、より大きな中空の細胞に成長する。このように表皮中層細胞のコルク様の特異的細胞構造と表層細胞の頻繁な剥離が本種の干潟上で生ずる皮膚の乾燥や紫外線障害の防止に役立ついると推定され、発達した表皮内毛細血管網も皮膚呼吸に極めて合目的な構造と考えられた。しかし、本種の皮膚は陸上動物のような厚い角質層を欠くことから、この表皮構造では陸上化には不十分と考えられる。このようなことから、両生的生活形態を有する本種の特異的表皮構造は陸上動物表皮の生態的適応とは異なった魚類特有の表皮構造の特殊化にあるものと解釈される。

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