



Fig 4. A. A part of a very young large mucous cell of *P. cottoides*, showing close relation of developing mucous droplets to the Golgi complex. $\times 18,000$. B. Basal part of a fully mature large mucous cell of *P. cottoides*, showing enormous accumulation of mucous droplets which compress other cell organelles against the cell membrane. $\times 4,000$. bl, basal lamina; cl, collagenous lamellae. Other latters, vide Fig. 2.

are called mucous droplets or vesicles. Nuclei having dense, finely granular, relatively homogeneous nucleoplasm were eccentrically located in the cells. The cytoplasm possessed a few mitochondria with sparse cristae, some Golgi complexes, and an abundance of rough-surfaced endoplasmic reticula which were oriented in parallel array (Fig. 2A). A considerable part of younger mucous cells was occupied by a number of mucous droplets containing fibrillar material. Individual mucous droplets, spherical or ovoid in structure with variable sizes, had a similar degree of electron opacity. Mucous droplets appeared closely related to both the Golgi complex and rough-surfaced endoplasmic reticulum, and developing ones were situated usually at the concave surface of the Golgi lamellae (Fig. 2B). Occasionally interdigitations were seen between mucous cells and filament-containing cells. Desmosomal attachments were very rarely observed. Cytoplasmic tonofilaments were also invisible in the cytoplasm of mucous cells. Mature mucous cells located near the surface of the epidermis were so full of mucous droplets that nuclei and cytoplasmic organelles were displaced to the peripheral and basal parts of the cells (Fig. 3A).

The large mucous cell: Very young large mucous cells were recognized by mucous droplets in the base of the mid-layer of the epidermis (Fig. 3B). The characteristic cytoplasmic features of these cells were abundant mitochondria, a considerable number of Golgi complexes and a few rough-surfaced endoplasmic reticula. Free ribosomes and vesicular or tubular structures enclosed by smooth-surfaced membranes were also found. The mitochondria were found throughout the cytoplasm and were not concentrated in the perinuclear zone. A non-lobulated nucleus was centrally located, and a membrane-limited body similar to that described by Merrilees (1974) in secretory cells of *Esox americanus* was seen near the nucleus (Fig. 3B). Peripheral cytoplasm contained a number of cytoplasmic tonofilaments, most of them connecting to the attachment plaques of the desmosomes found between large mucous cells and neighbouring filament-containing cells

(Fig. 3B, C). These two types of cells were interwoven by numerous finger-like projections (Fig. 3B, C). Young mucous cells had several mucous droplets, with considerably high electron opacities and variable forms, enclosed by smooth-surfaced membranes (Figs. 3B, 4A). Because lamellae and vesicles of the Golgi complex adjacent to the smallest mucous droplets contained a material of a similar opacity as the developing mucous droplet, the formation of mucus seemed to be closely associated with elements of Golgi complex (Fig. 4A). However, in the large mucous cells developing mucous droplets did not show such a definite orientation to the Golgi lamellae as that described for the small mucous cell. Vesicular or tubular structures containing a material with moderate electron opacity were occasionally seen to be situated close to the developing mucous droplets. As more mucus was formed, mucous cells enlarged considerably, and at maturity the cells were so full of mucous droplets that the nuclei and other cell elements were compressed to the peripheral and basal edge of the cell (Fig. 4B). Mucous droplets of mature cells were banana-like, tubular or ovoid in shape, with various sizes and degrees of electron lucidity. Longer mucous droplets measured about $6\ \mu\text{m}$ in length and about $1\ \mu\text{m}$ in width, and the broader were about $4.5\ \mu\text{m}$ in length and about $2.2\ \mu\text{m}$ in width. In releasing mucous substances, individual mucous droplets were shed with or without the breaking-down of compartmentalizing membrane (Fig. 1C). When mucous cells developed fully, finger-like projections mentioned above became less prominent. As described already, most of the mature cells occupied nearly the entire height of the skin epidermis.

Discussion

Mucous cells in the skin epidermis of *Protopterus annectens* are classified into three types according to the size and electron opacity of the mucous droplets (Kitzan and Sweeny, 1968). However, none of these three types show remarkable differences in their cytoplasmic features other than mucous droplets. Two types of mucous cells, i.e. small

and large described in the present study, differ from each other not only in the size of mucous droplets but also in features of the cytoplasmic organelles. Small mucous cells have similar cytoplasmic characteristics to those of typical mucous cells described by Wellings et al. (1967), Henrikson and Matoltsy (1968), Brown and Wellings (1970), and Harris and Hunt (1975); the cells possess well-developed rough-surfaced endoplasmic reticula and a considerable number of Golgi complexes. That the rough-surfaced endoplasmic reticulum (ergastoplasm) and Golgi complex play important roles in mucus-formation of such typical mucous cells was ascertained by Bierring (1962), Freeman (1962), and Neutra and Leblond (1966a, 1966b) in intestinal goblet cells of mammals. Furthermore, Henrikson and Matoltsy (1968) inferred that mucogenesis in the epidermal mucous cell of some teleosts appears to involve an unidirectional transport from the ergastoplasm through the Golgi complex to the mucous droplets. Although this unidirectional transport could not be confirmed in the present observations, there is little doubt that mucus-formation in small mucous cells is accomplished by cooperation of these two cytoplasmic organelles. According to Brown and Wellings (1970), abundant mitochondria are a feature of early mucous cells of *Hippoglossoides elassodon*. This problem cannot be answered until very young small mucous cells are examined.

Large mucous cells, unlike small ones, have no well-developed rough-surfaced endoplasmic reticula. Accordingly the mucogenesis of large mucous cells seems to be carried out by a somewhat different process from that of small mucous cells; the Golgi complex is considered to play a main role in the mucus-formation, and the vesicular or tubular structures described above would seem to contribute to this process, though morphological evidence is insufficient. Generally speaking, mucous droplets contained in young large mucous cells have higher electron opacity than those of nearly mature or mature cells. This may reflect differences between young and mature mucous cells in the protein and carbohydrate contents of the mucous droplets, because proteins are usually less osmophilic than

carbohydrates. A distinct cytoplasmic feature of large mucous cells is the presence of abundant mitochondria, even at nearly mature stages. That the plasma membrane of these mucous cells has a considerable number of desmosomal attachments between adjacent filament-containing cells is also noticeable, because desmosomes are rarely found in the majority of mucous cells of teleosts (Henrikson and Matoltsy, 1968; Roberts et al., 1971; Merrilees, 1974; Harris and Hunt, 1975; and others). According to Brown and Wellings (1970), the presence of desmosomes between mucous cells and filament-containing cells supports the idea that both of these cells arise from a common epithelial precursor.

The goblet cells of *Protopterus annectens* are classified into three types, according to different reactions to PAS (Kitzan and Sweeny, 1968). Small and large mucous cells treated in the present paper also show a difference in PAS-positive reaction: the former is weak, whereas the latter is intense. From the PAS reaction and some histochemical tests described, mucus contained in small mucous cells may be expected to be a bit different from but similar to that contained in large cells. In any case, histochemical analyses as those done by Asakawa (1970) and Yamada and Yokote (1975) in adult Japanese eel should be performed thoroughly on the contents of these two cells. This problem will be reported elsewhere.

According to Mittal and Munshi (1971), the air-breathing freshwater catfish, *Heteropneustes fossilis*, has both spherical and flask-shaped mucous cells in the skin epidermis, but these two appear to be of the same type: the former may be the initial stage of the latter and migrates towards the outermost layer where it ultimately becomes the flask-shaped cell. As described, both small and large mucous cells in the two cottids described here are found in the mature secretory stage. Accordingly, these two types are distinctly different and do not seem to transform from the one type to the other.

The skin epidermis of five cottids investigated previously by the author (Satō, 1967) was furnished with either larger mucous cells alone or with mucous cells of one kind and

sacciform granulated cells. The present two cottids, however, have the sacciform granulated cells in addition to two types of mucous cells in their skin epidermis (Satō, 1978, and Fig. 1B of the present paper). Unusual development of skin glands in fishes may be related to their special living habits such as those of some Indian air-breathing teleosts (Mittal and Munshi, 1971) and *Lepadichthys lineatus* living on and among the arms of shallow-water Red Sea crinoids (Fishelson, 1972). The skin epidermis of the present two cottids is rather luxuriously equipped with unicellular glands, though these two cottids exhibit no unique living habits. It seems, therefore, necessary to make a comparative study on the skin of cottids extensively. Mittal and Agarwal (1977) discussed the physiological significance and mutual action of mucous cells and sacciform granulated cells in the skin epidermis of *Monopterus couchia* by cytochemical analyses. The presence of complicated mutual action between these two secretory glands may be expected in the epidermis of the present two cottids also, but cannot be established until the chemical properties of these glands have been fully elucidated.

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- アサヒアナハゼおよび *Furcina* sp. の皮膚表皮にみられる大小2種の粘液細胞の微細構造
- 佐藤光雄
- カジカ科魚類のアサヒアナハゼと *Furcina* sp. の皮膚表皮には、大小2種の粘液細胞がみられる。これら2種の粘液細胞は単に大きさが著しく異なるのみでなく、微細構造にもそれぞれの特徴が認められる。しかし、大小の粘液細胞の微細構造は、上記2魚種間で大きな差異がない。小粘液細胞は、多くの典型的な粘液細胞と同様に、よく発達した粗面小胞体と、かなりの数のゴルジ体をもっており、粘液形成はこれら2種の細胞小器官の共同作用によるものと考えられる。大粘液細胞では、粗面小胞体の発達が悪く、かなりの数のゴルジ体と豊富なミトコンドリアが認められる。従ってこの場合の粘液の形成過程は、小粘液細胞のそれと幾分異なることが予想される。また大粘液細胞と隣接の表皮細胞との間に、相当数の接着斑が存在することも注目される。上記の2魚種の皮膚表皮には、大小の粘液細胞のほかに、嚢状顆粒細胞も多く認められる。これらの単細胞腺からの分泌物が、表皮面で複雑に作用し合うものと思われるが、この問題については、今後の研究をまわって、あらためて報告したい。
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