Fine Structure of the Terminal Buds on the Barbels of Some Fishes.

The terminal buds (end buds, beaker organs) of the fish were first observed by LEYDIG (1851) under the name of "becherförmiges Organ". Already in a few years after that, morphological details of the structure had been elucidated to the extent that reached almost the limit of the light microscopic observation, even estimated today (SCHULZE 1863, SCHWALBE 1868, NAGEL 1894 etc. See KOLMER 1927 for the review). Similar structures were then found in almost all the vertebrate series above fishes, and the functional meaning of them seemed to have been established as the "taste buds". As for the terminal buds of the fish in particular, the general conclusion of various morphological and physiological studies was that they are homologous with the taste buds of higher vertebrates. However, those buds in fishes, which were found both inside and outside of the oral cavity particularly on the barbels were considered to be sensitive to some additional kinds of stimulus other than chemical, and were thus named "Wechselsinnesorgan" (KOLMER 1927).

Though considered to be homologous with, the terminal buds of the fish have been found to show some structural differences from the taste buds of higher vertebrates. In the terminal buds of fishes, two kinds of cells (sensory and supporting cells) can be identified rather easily as compared with the cases of higher vertebrates, and nerve fibers, having entered the buds, first make the basal plexus before branching into fine fibers and ascending between the cellular elements (KOLMER 1927). Few intensive works on these structures, except for some genetic and histochemical investigations, had been further attempted, until the electron microscope was applied to the morphological analysis of them. This new approach has given us a large amount of knowledge on the structures in problem, particularly on the apical differentiation of the taste cells and on the neuro-epithelial relationships, although the results thus obtained so far are confined mostly to the taste buds of mammals (TRUJILLO-CENOZ 1957, DE LORENZO 1858, MURRAY and MURRAY 1960, NEMETSCHEK-GANSLER and FERNER 1964, FARIBMAN 1965, GRAY and WATKINS 1965 etc.); the terminal buds of the fish have escaped scrutinizing attacks of electron microscopy except for the short report of TRUJILLO-CENOZ (1961) and the quite recent work on the apical region of sensory cells made by DESGRANGES (1965).

The present author could find electron microscopically some peculiar structural characteristics to be reported here that have not been pointed out in mammalian taste.
buds. These morphological findings may partly explain the characteristic physiological properties of the terminal buds found recently by KONISHI (1964).

I. Materials and Method.

Barbels from three species of fresh water fishes: carp (Cyprinus carpio L.), cat fish (Parasilurus asotus L.) and loach (Cobitis biwae Jordan and Snyder) were used in the study. The palatal organ of the carp was also studied for comparison. The materials were fixed in MILLONIG's (1961) fixative or in 2% osmium tetroxide buffered with s-Collidine (BENNETT and LUFT 1959), dehydrated in ethanol series and embedded in Epon-epoxy resin (LUFT 1961). Thin sections cut on a Porter-Blum microtome were stained with lead tartarate (MILLONIG 1961) and were observed on the HITACHI-Hs 7 electron microscope. Thicker sections were stained with buffered toluidine blue (YAMAMOTO 1963) to be studied light microscopically.

II. Observations and Discussion.

Light microscopy (Fig. 1 to 4).

The terminal buds, giving apparently the same appearances as those found in mammalian taste buds, can be found on the entire length of the barbels in all the species examined, although they are more abundant in the distal part of the barbels in general. They are usually ovoid in shape and extend through the entire thickness of the epidermis, lying upon the somewhat raised papillae of the dermis. They are 45 to 75 μ in length and 30 to 50 μ in width. The cells constituting the buds are of elongated, cylindrical to spindle form, being thickest at the nuclear region in the basal half of the bud and tapering towards the free surface or the apex of the bud, to end with fine, pale processes (Fig. 1). The apex of the bud either protrudes outwards from, (Fig. 3) or retracts from (Fig. 1) the level of the surrounding epidermis, and is not covered with a keratinized, dense homogeneous material or blackish membrane (HEIDENHAIN 1914) which can be found in the external taste pore of the mammalian taste buds. At the apical region of the buds, we can distinguish sometimes two types of cells, light and dark ones (Fig. 1). Whether the fine, pale processes above mentioned stick out from light cells or dark ones, or from both types of cells, is not obvious. In the subapical region, this distinction of two types of cells is not strictly made and all the component of the buds give rather light, pale appearance. In the thickest portion of the bud, or the nuclear region, we can occasionally, particularly in carps, distinguish between two kinds of nuclei: pale, light nuclei with rather smooth contour and dark ones with irregular, indented contour. In the deepest part or the innermost pole of the bud, there exists in most cases a cell of a particular type, perhaps corresponding to the "basal cell" which has been described in mammalian taste buds (HERMANN 1884, HEIDENHAIN 1914). The long axis of this cell is perpendicular to the long axis of the other cellular constituents of the bud and to that of the bud itself, and appear as making the innermost border of the buds against the subepithelial papilla of the connective tissue. This type of cell has lighter nucleus than the other cellular elements of the buds, and has rather scanty cytoplasm. Between this basal cell and the nuclear region of other cellular constituents, there can
Terminal Buds of the Fish Barbels.

be found a lot of tiny, light spots which are occasionally seen continuing to the nerve bundles which enter from the subgemmal papilla into the bud (Fig. 2, 3); they are thus considered to represent finer nerve branches, or the intragemmal nerve plexus. There were no clear indications of transition between the surrounding epithelial or underlying connective tissue cells and the cellular elements of the buds, as such suggested to be the case in the mammalian taste buds (KOLMER 1927). Neither were there any mitotic figures of cells in the buds (HERMANN 1884). In the subgemmal papilla there can usually seen capillary loops, connective tissue cells and bundles of non- or thinly myelinated nerve fibers (Fig. 4).

**Electron microscopy.**

Under the electronmicroscope, we can distinguish, in addition to the basal cell identifiable already at the level of light microscopy, further two kinds of cell in the terminal buds: receptor cells and supporting cells.

Light-microscopic distinction of these two kinds of cell in the fish has been said to be easy, especially in the silver impregnated materials (KOLMER 1927, SCHULZE 1867, LENHOSSEK 1893, DOGIEL 1897), and they were also distinguished in the electron microscopic observations (TRUJILLO-CENÓZ, 1961, DESGRANGES 1975). In higher vertebrates, particularly in mammals, on the contrary, distinguishing cell
types is not so easy and has been much disputed with no definite conclusions as yet (cf. DE LORENZO 1963, FABLMANN 1965).

The receptor cells in the terminal buds of the present materials are characterized by: 1) specialized apical formations which may correspond to the sensory hairs or sensory processes recognizable with the light microscope, 2) presence of characteristic electron dense tubular structures in the apical half of the cytoplasm and 3) intimate relationships or particular junctions with the nerve elements.

The supporting cells, on the other hand, have abundant intracytoplasmic filaments, seemingly corresponding to the tonofibrils of light microscopy, and well developed Golgi-apparatus, and apparently lack the specified junctions with neural elements. We encounter sometimes, however, the cells which are of transitional or intermediate form and cannot be classified into any of the three kinds of cells above enumerated. These atypical cells, however, are met only occasionally and are considered to be either undifferentiated or degenerated cells. Such a transitional form of cell has been reported also in light microscopy of the terminal buds in some fishes (MAY 1925).

1. Receptor cells: In the apical region, both receptor cells and supporting cells have rather smooth and slender contours and there occur scarcely any interdigitations between them, in marked contrast to the intercellular relationships in the surrounding squamous epithelial cells (Fig. 7). The upper free surface of the receptor cells is not provided with ordinary microvilli, but with single or two apical processes of a characteristic appearance. These are sometimes spindles (Fig. 5) or elongated rods, attached to the cell body with narrow stalks (Fig. 6). Sometimes they appear as simple protrusions or prolongations of the upper pole of cells into the free space (Fig. 8). These apical processes are 1.5—3 μ or more in length and approximately 0.5 μ in diameter at the thickest portion. These have generally electron lucid matrix as compared with the lower portions of receptor cells or with the supporting cells and are not provided with any perceivable intracytoplasmic organelles such as mitochondria and vesicles. These apical processes have been recognized by light microscopic observations (KOLMER 1927) as sensory hairs or sensory rodlets (Sinnesstiftchen). According to SCHULZIE (1863, 1867) who made the first detailed observations on the terminal buds of fishes, these sensory hairs can be found 20—40 per a bud. These apical processes have been considered of particular functional importance as the site of the first transductive activity of the receptor cells and have attracted attentions of electron microscopic investigators. The electron micrographs of the processes in question in the present work and those of DESGRANGES (1965) are significantly different from those of the mammalian taste bud described by NEMETSCHEK-GANSLER and FERNER (1964), DE LORENZO (1963) and others. DESGRANGES (1965) described five types of sensory cells according to the shape of the apical processes. In the present study, too, the author could observe, as was stated above, some different types of processes of sensory cells, but it is not certain as yet, as was pointed out by DESGRANGES (1965), if there exist several types of sensory cells, each of them having a specific type of apical processes. It seems also possible, moreover, that these different structures of the apical processes represent only the dif-
Terminal Buds of the Fish Barbels.

Different functional stages of the receptor cells. Above and between these apical processes of the receptor cells and the microvilli of the supporting cells, there could be recognized no extracellular dense materials which have been demonstrated in the mammalian taste buds (HEIDENHAIN 1914, DE LORENZO 1963, NEMETSCHEK-GANSLER 1964).

In the apical portion of the receptor cell immediately below the characteristic

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Fig. 5-8. Electron micrographs of the apical regions of terminal buds. S supporting cells, R receptor cells, P perigemmal cells, apr apical processes of the receptor cell, dt dense tubules. Fig. 5: cat-fish, ×1,400, Fig. 6: carp, ×20,000, Fig. 7: carp, ×18,000, Fig. 8: carp, ×20,000.
Fig. 9, 10. Cross sections of the apical region of the terminal buds. The plane of Fig. 9 is somewhat upper than that of Fig. 10. Cross section of dense tubules in the receptor cells (R) and filamentous structures in the supporting cells (S) can be seen. In Fig. 10, well developed Golgi-apparatus (g) in the supporting cells is notable. Compare these sections with the longitudinal sections of the same region in Fig. 12 and 13. P perigemmal cells. Carp barbel, ×11,000.
apical processes, there appear plenty of vesicles of about 50 m\(\mu\) in diameter which are more crowded in the peripheral part of the cytoplasm (Fig. 5, 7, 8). Towards the lower region, these vesicles become to be fused with each other (Fig. 8, arrow) to form tubular structures which represent the most abundant and prominent intracytoplasmic organelles in the subapical and supranuclear regions of this cell. These tubular structures (Fig. 11, 12, 13) are about 40 to 55 m\(\mu\) in diameter and considerably electron-dense as compared with other tubular and vesicular intracytoplasmic formations. These tubules are usually more or less straight and aligned along the long axis of the cell (Fig. 12 and 13), although they may sometimes be tortuous or spiral in appearance (Fig. 11). When sectioned perpendicular to the long axis of the cell, these tubules appear as vesicles with dense amorphous contents in them (Fig. 9 and 10).

These tubules may have a particular functional meaning in the chemoreceptive activity of cells, but structures similar to these have not been observed hitherto, either in fish terminal buds or in mammalian taste buds.

As other structures in the supranuclear cytoplasm, there are recognized smooth-surfaced endoplasmic reticulum and elongated mitochondria aligned in parallel to the long axis of the cell; in the juxta-nuclear region in particular, where the dense tubules are few, there exist Golgi-apparatus, rough-surfaced endoplasmic reticulum, dilated smooth-surfaced endoplasmic reticulum and crowded free ribosomes (Fig. 13).

The nucleus is ovoid in shape but its contour shows frequently shallow and deep indentations (Fig. 15). The most prominent structures found in the infranuclear
cytoplasm of the receptor cells are the large amount of vesicles of various sizes, ranging from 300 to 1000 Å (Fig. 15, 16). A considerable part of these vesicles are assembled to the particular areas of the plasma membrane to which the nerve fibers or terminals are in apposition. At some of these sites, the plasma membranes in apposition show certain degree of increase in electron density, or of membrane thickening, and the distance between the apposed membranes is rather constant through that area as compared with the cases of apposition of plasma membranes of the receptor cell and the supporting cell (Fig. 15, 16). These specialized relationships between certain portions of receptor cells and nerve elements have a remarkable similarity to the synaptic contacts found in the central nervous systems. TRUJILLO-CENÜZ (1961) who studied the fish terminal buds electron microscopically could observe, however, neither specialization of the plasma membranes, nor accumulation of mitochondria and vesicular structures at the areas where the receptor cell and nerve element are in contact with each other.

Fig. 13. Apical and juxtanuclear regions of a receptor cell of the loach barbel. R receptor cell, dt dense tubules, g Golgi-apparatus, S supporting cell, × 20,000.
2. **Supporting cells**: These are of slender cylindrical, or elongated spindle form, in resemblance to the receptor cells. However, the lower portions of these cells, not
like the receptor cells which end in rather blunt base, ramify themselves in a complicated way to thrust their branches among other elements of the basal region of the buds, i.e. basal portions of receptor cells, nerve fibers and terminals and the basal cell (Fig. 15). These characteristics in gross configurations, particularly of the basal...
portion, of the supporting cells have been noted since early by light microscopy of
the isolated cells (SCHULZE 1863) and of silver impregnated materials (DOGIEL
1897).

The free surface of the supporting cells is provided with a few but rather regular
microvilli, 100—200 mµ in diameter and 0.5—1 µ in length (Fig. 5 to 8). The most
characteristic intracytoplasmic structures of these cells are numerous fine filaments
of approximately 50 A in diameter, which run, either in bundles or in diffuse way,
throughout the whole extent of the cytoplasm from immediately below the free
surface to the fine basal branches. These filamentous structures seem to correspond
largely to "Stützfibrillen" of light microscopy (KOLMBR 1927). LEYDIG (1851)
noted the similarity of these fibril containing cells to the smooth muscle cells ("mus-
kulöse Faserzelle") and he ascribed the contractility of the terminal buds he observed
to these fibrous cells. Whether this assumption of LEYDIG is valid or not is not
decided as yet, but the filamentous materials in supporting cells are considered to
be likely responsible for the mechanical support, serving as the skeleton of the buds.

Immediately below the free surface, most of these filaments run in peripheral
portion of cells in the direction perpendicular to the axis of the cells and are occasion-
ally found to be connected to the areas of desmosomal junctions made between the
supporting cells, or between the supporting cell and the receptor cell or the perigem-
mal cells (Fig. 5 to 8). At a little distance above these desmosomal junctions, areas
of the tight junction are generally found. In the vicinity of the free surface, vacuoles
of various dimensions and configurations occur in some cases (Fig. 7 and 8), which
DESGRANGES ('65) considers to be the characteristic structures of this region.

Well developed Golgi-apparatus is also a characteristic feature in the supranuclear
cytoplasm. Its elements can be found particularly in abundance in the peripheral
cytoplasm near the nucleus, and are extended in parallel to the plasma membrane
(Fig. 12 and 10). Besides, there can be found mitochondria, small and large vacuoles,
smooth and rough surfaced endoplasmic reticulum and free ribosomes. The infranuclear
portions of the supporting cells, as stated already, are divided into branches which
intervene other elements of the basal region of the bud (Fig. 15), thus resembling the
situation in the glial elements of the central nervous system. Most of these branches
or foot processes do not reach the basement membrane which underlies the base of the
bud, but a few branches located in the most peripheral portion of the base of the bud
are occasionally seen in direct contact with the basement membrane.

The boundaries between the supporting cells and between the supporting cell and
the receptor cell are rather smooth and such specified junctional structures as desmoso-
mal system and intercellular digitations are only rarely encountered (Fig. 9 and 10),
except for the area immediately below the free surface, where, as stated above, the
junctional complex is constantly present (Fig. 5 to 8). Supporting elements, never-
theless, surround or envelop nearly the whole surface of the receptor cells, except
for the luminal surface and the sites of apposition to nerve elements.

Precise and definite electron microscopical identification of the supporting cells
in the terminal bud has not been made so far and the same holds true on the mammal-
ian taste buds. This makes it difficult to establish the homology of cellular con-
stituents of the bud structures of vertebrates.
The type I cell in the taste bud of the rabbit observed by FARBMAN (1965) seems to correspond to the supporting cell of the present material, in particular in respect to the relationship to the nerve elements. He observed invariably one and frequently two or more nerve processes being enveloped by sheet-like cytoplasmic extensions of these cells in a fashion identical to that of Schwann cells, making "mesoaxon". In the present materials, however, there could not be found the formation of mesoaxon. The supporting cells presented here resembles to a certain degree those described by HAMA (1965) in the lateral line organ of the Japanese eel, in the points of similarly arranged abundant filamentous structures, well developed Golgi-complex of the similar settlement and the relationships with the receptor cells. On the other hand, the regularly arranged rough surfaced endoplasmic reticulum, and the well developed interdigitations and desmosomal systems with neighboring cells as described by HAMA lack in the present cases.

Functional implications of the supporting cells in the lateral line organ was suggested by HAMA (1965) as consisting in 1) a nutritive function for the receptor cells, 2) mucous secretion and cupula formation, 3) sustaining the receptor cells in cytoplasmic network made by the adhesion of supporting cells to each other, 4) insulation of receptor cells, and 5) role as Schwann cell for intraepithelial nerve fibers. Though not all of these functional meanings seem to be the case in the terminal bud, the latter three might well explain the morphological situation of the supporting cells in the present materials.

3) The basal cell (Fig. 14, 15, 17 to 20): This lies directly on the basement membrane and forms almost full extent of the deepest boundary of the terminal bud, except for a small portion where some of the foot processes of the supporting cells reach the basement membraen or where nerve bundles enter from below into the bud. The shape of this cell seems to be a disc of rather smooth contour with central thickening. Its oval or elipsoid nucleus with shallow indentations lies approximately in the center of the cell body. The cytoplasm with rich intracytoplasmic formations extends in tapering towards the periphery. Mitochondria, though abundant, are smaller in size as compared with those in the receptor and supporting cells, but larger than those in the intragemmal nerve elements. A lot of small (300—600 Å) and large (600—900 Å) vesicles are also found in the basal cell cytoplasm. Some of the smaller vesicles are often found aggregated to the portion of the plasma membrane where a nerve element makes contact. At such places, the distance between the plasma membranes of the basal cell and the neural element is slightly wider than at the site of contact between the basal cell and the nerve element or the supporting cell process where the accumulation of the smaller vesicles is not evident. At such specialized type of contact, furthermore, the basal cell cytoplasm in the immediate vicinity of the site of contact has gained higher electron density than the surrounding areas (Fig. 17 to 20). At the region of contact with basal processes of the supporting cell, on the other hand, desmosomal systems are formed occasionally (Fig. 15, arrow). Larger vesicles are often seen containing dense cores of 300—500 Å in diameter (Fig. 18). Multi-vesicular bodies (Fig. 18), smooth and rough surfaced endoplasmic reticulum, free ribosomes and fine filamentous structures (Fig. 17) are other intracytoplasmic organelles of the
Terminal Buds of the Fish Barbels.

The basal cell was described for the first time by HERMANN (1884) in the taste buds of some mammals. While GRÅBERG (1899), HEIDENHAIN (1914) and others confirmed its presence, some investigators denied to define it as an independent type of cell, considering it to be the obliquely sectioned figure either of a receptor or a supporting cell (LENHOSSEK 1893, REZIUS 1912) or of a cell in the subepithelial connective tissue (EBNER 1912). The present observation in fish terminal buds showed the basal cell as an independent cell type, in respect to its specific position in the bud, its cytoplasmic organelles and the relationship with neural elements. In the taste buds of the monkey, MURRAY and MURRAY (1960) found, electron microscopically, basally placed nuclei which were separated from the connective tissue by a basement membrane and their cytoplasmic expansions could frequently be traced all the way to the taste pit. They could not, however, go so far as to realize these cells as fundamentally different from others. On the other hand, FARBMAN (1965) in his electron microscopic observation of rat’s taste buds, could recognize the basal cell as a particular cell type, which coincides to a considerable extent with the basal cell in the present observation, especially in respect that it is in contiguity with at least one intraepithelial nerve process and that membrane bounded vesicles (400—700 Å) in the cytoplasm are accumulated near the area of contact with nerve ele-

Fig. 17—20. Portions of the basal cells, showing their relationships with other elements of the basal region of the bud. B basal cell, n nerve elements, S supporting cells. Specialized contacts between parts of the basal cell plasma membrane and nerve elements are evident in Fig. 17, 19 and 20. In Fig. 18, cored vesicles (arrow) in the nerve elements and the basal cell cytoplasm, and a multi-vesicular body in the basal cell are shown. Fig. 17 and 20: loach, ×19,500 and 28,000 respectively. Fig. 18 and 19: carp, ×10,500 and 28,000 respectively.
ments. According to the early light microscopic observations, the basal cell extends numerous fine cytoplasmic processes in all directions; those extending basally are connected with the subepithelial stroma and those ascending pass over the protoplasmic fibers of the supporting cells (HERMANN 1884). These situations could not be confirmed in the present observation.

As to the functional meaning of the presence of the basal cell, FARBMAN (1965) considers it as the cell in the intermediate stage in the course of the differentiation of peripheral cells into the typical spindle-shaped cells of the taste organ. The present author, considering its localization and the specialized relationship of it with neural elements, is inclined to suppose that the basal cell might represent a particular type of receptor cell, or "accessory receptor cell", which would be activated by the stimulus different in nature from those activating the ordinary, or chief receptor cells situated over the basal cell. Thus, the bud may be, as the earlier investigators considered, a multi-sensory organ ("Wechselsinnesorgan"). With regard to this assumption, of course, further physiological explorations must be made.

4) The innervation of the terminal bud: In the core of the barbel, several pairs of bundles of myelinated nerve fibers which are considered the branches of the facial nerve can be found, whereas in the raised papillae of the dermis underlying the terminal buds, none or few of myelinated, but some bundles of unmyelinated fibers are recognized. This seems to imply that the nerve fibers lose their myelin sheath on branching from the larger bundle of myelinated fibers, on entering the papilla to innervate the bud. The unmyelinated fibers, ranging from 0.3 to 1 μ in diameter, are accompanied by Schwann cell (Fig. 15), but the distinct formation of the mesaxon could not be seen. On entering from below into the basal portion of the bud (Fig. 14), passing by the side of the basal cell, these bundles lose the Schwann cells accompanying them, whose role seems then to be substituted by the foot processes of the supporting cells. The fibers having entered the bud seem to branch further to make an intricate intragemmal plexus, some components of which making particular contacts either with the receptor cells (chief receptor cells) (Fig. 15 and 16) or with the basal cell (accessory receptor cell) (Fig. 17, 19 and 20). Nerve elements can be seen exclusively in the basal portion of the bud, and were never identified in the nuclear and more upper regions of the bud, where light-microscopic observations of silver impregnated specimens have shown neural elements.

The nerve fibers within and immediately below the bud (Fig. 14) contained definite neurofilaments, mitochondria of smaller size, multi-vesicular bodies, cored (Fig. 18) and non-cored vesicles of variable dimensions. These vesicular structures in the nerve elements, though found considerably often, present scarcely any definite association to the restricted, particular part of the axolemma, not like what the vesicles in the lower part of the receptor cells or in the basal cell are to the area of the plasma membrane to which the nerve element is in apposition.

The way of innervation of the buds was known, already in early light microscopic observations of methylene-blue preparation or of silver-impregnated materials, to show wide variety among species and classes of animals. Particularly remarkable differences have been noted between the fish, reptile and amphibia on one side and
the mammal and bird on the other side. In electron microscopy, too, one can note considerable variations even among mammals (DE LORENZO 1958, MURRAY and MURRAY 1960, GRAY and WATKINS 1965, FARBMAN 1965). In mammalian taste buds, the sites of contact between neural elements and the receptor cells generally seem not to show such obvious specializations as observed in the present work on the fish terminal buds, i.e. the membraneous thickening and the aggregation of vesicles in the receptor cells. Although GRAY and WATKINS (1965) described in the taste buds of the rat rows of dense projections spaced along the presynaptic membrane, this type of membrane specialization was not found in the present materials.

III. Summary.

The terminal buds from three species of fresh water fishes (carp, cat-fish and loach) were examined electron microscopically. The buds consist of three types of cells and of nerve elements innervating the buds.

1. The receptor cells are characterized first by the presence of specialized electron-lucid apical processes which show wide variety in dimension and form. The supranuclear cytoplasm contains numerous electron-dense tubules of 400—600 Å in diameter, sometimes running straight along the axis of cells, or sometimes presenting tortuous or spiral appearances. The infranuclear portion has abundant vesicles, 300—1000 Å in diameter. Some of these vesicles assemble to the particular site of contact of the cell with nerve element and resemble those in the synaptic regions in the central nervous system.

2. The supporting cells contain abundant filaments through the whole extent of their cytoplasm, from just below the free surface with microvilli, to the fine sheets which are formed by branching of the infranuclear part of the cell and intervene the various elements in the basal portion of the bud.

3. The basal cell is placed at the bottom of the bud directly on the basement membrane and contains numerous small and large vesicles. Some of the larger ones contain dense cores in them, while not a few of the smaller ones are accumulated to the specialized site of contact with neural element, presenting seemingly the same situation as was found between the receptor cells and the neural element.

4. The myelinated fibers in the core of the barbels branch into finer unmyelinated fibers which proceed into the raised papilla of the dermis underneath the bud to reach the base of the latter. After having entered the bud, the fibers seem to divide into finer branches, which, forming the intragemmal plexus, have a specified contact with either the receptor cells or the basal cells. On the bases of these findings, possible functional implications of the morphological constituents of the terminal buds were discussed.

内容自抄。

三種の淡水魚（コイ、ナマズ、ドジョウ）のひげに存在する終末蕾の構造を電子顕微鏡で観察した。終末蕾は受容細胞、支持細胞、基底細胞および神経要素より成る。
1. 受容細胞は、自由面に特異な電子密度の低い突起を有し、核上部胞体内に
は、電子密度の高い、径400〜1,000Åの小管構造を多数容れる。核下部胞体内に
は300〜1,000Å径の、多数の小胞を有し、これらの一部は、神経要素と受容細
胞が接する部分に集合し、またそのような場所では受容細胞の形質膜および神経
要素の形質膜の肥厚が認められ、また膜間距離も他の部に比し、やや広く、かつ
一定である。これらの場所における受容細胞-神経要素の形態学的関係は、中枢神
経におけるシナプスに酷似する。

2. 支持細胞は胞体内に多数の細線維構造を有し、このものは、自由面直下よ
り、細く枝分しする基底部に至る全胞体中に存在する。また特に核上部胞体内内
には、多数のゴルジ装置をもつ。支持細胞基底部の、多数の細い突起に分かれ、このも
のは基底部の種々の構成要素の間に入りこみ、あたかも中枢神経系におけるグ
リア成分のごとく状態を呈する。

3. 基底細胞は、基の最下部に存し、基底膜に直接する。胞体内には多数の小胞
を有し、このものの一部は、基底細胞形質膜が神経要素を接する場所に集合し,
この場所では、受容細胞が神経要素と接する部において見られたと同様の形態学
的特徴が見られる。

4. ひげの中心部に見られる有髄神経束より分枝し、騰髄を失なった線維群は,
基の下方の真皮乳頭中を、髄基底部に向かう。基底細胞の周囲より髄底部にはい
った無髄神経は、さらに細く分岐し、複雑な髄内神経叢をつくり、この構成要素
が受容細胞または基底細胞と、特異的な結合を行なう。

References.

de cellules sensorielles dans les bourgeois du goût des barbillons du Poisson-chat. C. R. Acad. Sci.,
261 (1965), P. 1095-1098. — De Lorenzo, A. J. D: Electron microscopic observations on the
taste buds of the rabbit. J. biophys. biochem. Cytol., 4 (1858), P. 149-150. — Studies on the
ultrastructure and histophysiologie of cell membranes, nerve fibers and synaptic junctions in
Gray, E. G. and K. C. Watkins: Electron microscopy of the taste buds of rat. Z. Zellforsch.,
66 (1965), P. 583-595. — Hama, K.: Some observations on the fine structure of the lateral line
Heidenhain, M.: Über die Sinnesfelder und die Geschmacksknospen der Papilla foliata des
S. 365-479. — Hermann, F.: Beitrag zur Entwicklungsgeschichte des Geschmacksorgans beim
Terminal Buds of the Fish Barbels.