Fine Structure of Autonomic Ganglion in the Chicken Pancreas*

Shigeharu Kudo (工藤重治)

Received October 9, 1970

A large number of histological investigations have been carried out on the innervation of the vertebrate pancreas at the light microscopic level (Zimmermann, 1927; Hagen, 1956; Honjin, 1956; Stöhr, 1957; etc.), and it is widely accepted that in the interlobular connective tissue of the pancreas there occur, along the paths of the nerves, small ganglia containing a small number of autonomic ganglion cells. In the present study the intrapancreatic ganglia of the chicken have been electron microscopically observed in detail, since, as far as the present author knows, intrapancreatic ganglion cells had hitherto been electron microscopically investigated by only two authors, Rhodin (1963) in the cat and Watari (1968) in the monkey and bat. On the other hand, the peripheral autonomic ganglia located in other sites of the body have been studied by many investigators and in various animal species with the electron microscope, such as the sympathetic ganglia by Palay and Palade (1955), Barton (1957), Taxi (1957), Barton and Causey (1958), Causey and Barton (1958), Wyburn (1958), Cravioto (1962), Grillo and Palay (1962), Pick (1963, 1967), Elfvin (1963a, b, 1968), Yamamoto (1963), Forssmann (1964), Pick, de Lemos and Gerdin (1964), Szentagothai (1964), de Lemos and Pick (1966), Hagen, Kodal and Wittmoser (1967), Unsicker (1967, 1969), Wechler and Schmekel (1967), Becker (1968), Hamori, Láng and Simon (1968), Yoshida (1968), Colborn and Adamo (1969), Seite (1969a, b) etc., and the parasympathetic ganglia by de Lorenzo (1960), Hess (1965), Takahashi and Hama (1965a, b), Dixon (1966), Takahashi (1967), Yoshida (1968), Hukuri (1969), and also intramural ganglia of the intestine by Hager and Tafuri (1959), Ruska and Ruska (1961), Kubozoe, Daikoku and Takita (1969) etc. The findings obtained by the above authors have been referred to in the present study on the autonomic ganglia in the chicken pancreas.

Material and Method

Small tissue blocks excised from the chicken pancreas were quickly cut into small pieces and fixed for 2 hrs in an ice-cold, 6.25% solution of glutaraldehyde buffered at pH 7.4 with 0.1M phosphate buffer containing 4.5% sucrose. After this initial fixation the pieces were washed in the same buffer containing 7% sucrose and postfixed in an ice-cold, 1% solution of phosphate-buffered osmium tetroxide containing 4.5% sucrose. Following rapid dehydration in a graded series of cold ethanol and treatment with propylene oxide, the pieces were embedded in Epon 812 (Luft, 1961).

The ultrathin sections were cut with glass knives on a Porter-Blum ultramicrotome and mounted on copper grids without supporting film. The sections were stained with uranyl acetate followed by lead acetate, and examined with JEM-7 and -7A type electron microscopes.

*This study was directed by Prof. Emer. Toshio Ito when he was the director of this department.
Observations

Perikaryon of the ganglion cell

In the chicken pancreas ganglion cells have often been found mainly in the interlobular connective tissue singly or in small groups along the paths of the nerves. They are always larger than exocrine and endocrine cells, being provided with a large, somewhat eccentrically located nucleus which contains a prominent nucleolus (Fig. 1). The nucleoplasm appears light in general and the chromatin particles are almost homogeneously dispersed throughout the nucleoplasm. In the nuclear envelope there occur a great number of nuclear pores measuring about 600 to 800 Å in diameter. In tangential sections of the nuclear envelope they show

![Image of a ganglion cell with labeled structures](image)

**Fig. 1.** An intrapancreatic ganglion cell of the chicken containing eccentrically located nucleus (N) and wrapped by an electron opaque cytoplasmic sheath of satellite cell (SC). The cytoplasm contains Golgi complexes (G), mitochondria (M), Nissl substance (NS) composed of rough-surfaced endoplasmic reticulum and an abundance of associated polysomes, and dense bodies (DB) or probable lysosomes. Around the ganglion cell there appear several profiles of dendrites (D) containing Nissl substance and ensheathed by dense satellite cell cytoplasm. CN connective tissue of the endoneurium, FB fibroblast, PC perineural cell surrounded by a basement membrane. ×4,800
round profiles margined with electron dense material and a central dense dot. Near the center of the nucleoplasm there occur occasionally spindle- or rod-shaped inclusions showing a parallel longitudinal fibrillar structure. In Figure 2 a probably cross-sectioned inclusion is seen on the right side of the longitudinal inclusion.

In the perikaryonal cytoplasm of the ganglion cells are distributed Golgi complexes, dense-cored vesicles (granular vesicles), mitochondria, rough-surfaced endoplasmic reticulum, free ribosomes, neurotubules, neurofilaments, dense bodies (probably lysosomes) and multivesicular bodies (Fig. 1–8). Many Golgi complexes are generally distributed around the nucleus and consist of stacks of elongated lamellae and a small number of vesicles. Golgi lamellae are frequently greatly dilated into irregular vacuoles. Variable numbers of dense-cored vesicles (granular

Fig. 2. A portion of the perikaryon of an intrapancreatic ganglion cell. In the nucleus (N) a spindle-shaped inclusion showing a paracrystalline fibrillar structure and, on the right side, another, probably cross-sectioned one are seen. In the perikaryonal cytoplasm numerous mitochondria (M), Golgi complexes (G), abundant Nissl substance (NS) and dense bodies (DB) with homogeneous matrix of low density are observed. The surface of the perikaryon is naked to a large extent, and covered directly by the basement membrane (BM). PF cross-section of a preganglionic nerve fiber. ×5,800

Ganglion in the Chicken Pancreas
vesicles) measuring about 1,000–1,500 Å in diameter are seen (Fig. 3, 8) which consist of a smooth membrane sac and a spherical central core of high electron density, and between both there is a narrow light halo. The dense-cored vesicles are frequently concentrated in the vicinity of the Golgi complexes. They are similar in dimensions and ultrastructure to the granular vesicles in the axoplasm of the unmyelinated preganglionic nerve fibers and synaptic endings (Fig. 9, 10, 16–26). Agranular vesicles, which are contained in the synaptic terminals, have never been found in the perikarya of the ganglion cells.

The Nissl substance or rough-surfaced endoplasmic reticulum of the ganglion cells in the chicken pancreas consists of elongated flattened cisternae or tubules
studded by ribosomes, which ramify and anastomose with each other making irregular reticulum distributed almost uniformly throughout the entire cytoplasm of the perikaryon; abundant free ribosomes mostly aggregated into rosette-like clusters are distributed in the ground cytoplasm between the cisternae. The cisternae do not show any dilatations and are filled with an electron-opaque homogeneous material. The ribosomes attached to the cisternae are relatively sparse (Fig. 3, 4, 8). Well-defined stacks of the rough-surfaced endoplasmic reticulum which deserves the name of Nissl bodies have been observed rather infrequently. Numerous mitochondria are randomly distributed exhibiting variably shaped profiles (Fig. 1–3). Some of them are remarkably elongated. Cristae mitochondriales are not numerous and are oriented in irregular directions. The matrix of mitochondria is generally electron opaque; vacuolar appearances of the mitochondria seem to be artifact (Fig. 1, 7, 8).

Fig. 4. A part of the perikaryonal cytoplasm of a ganglion cell. A Golgi complex (G), mitochondria (M) and Nissl substance (NS) of typical fine structures are seen. Besides membrane-bounded dense bodies (DB) with homogeneous matrix two dense bodies (↑) containing a finely granular material of higher electron density and elements with a myelin figure are observed. CN connective tissue of the endoneurium, D dendrite, PF preganglionic nerve fiber, SC somatic satellite cell. × 25,200
Abundant neurofilaments measuring about 100Å in thickness run in random directions and form loose bundles (Fig. 3, 5, 7, 8). The neurotubules (microtubules) of about 250–290Å in diameter are by far less numerous than the neurofilaments and run singly in irregular directions among the latter (Fig. 3, 5). The neurofilaments and tubules both are gathered toward the origins of the neuronal processes they center.

In the perikaryonal cytoplasm there are scattered a number of dense bodies of variable shapes and sizes which probably correspond to lysosomes. They are bounded by a smooth limiting membrane. In some cases their matrix is almost homogeneous and not so electron dense (Fig. 3), but occasionally they contain finely granular material of high electron density and dense areas showing a myelin figure (Fig. 4). In other cases the dense bodies are on the whole very electron dense (Fig. 1, 7, 8). Multivesicular bodies rarely occur near the Golgi complexes (Fig. 8).

Fig. 5. A part of a ganglion cell containing a nucleus (N). Note numerous round nuclear pores (NP) in which a central dense dot is recognized. In the perikaryonal cytoplasm, Golgi-complexes (G), mitochondria (M), Nissl substance (NS), a dense body (DB), abundant neurofilaments (NF) and a few neurotubules (NT) are seen. ×9,200

Somatic satellite cell

In the pancreatic ganglion of chickens, the cytoplasm of satellite cells is much more electron dense than the neuronal perikaryon and processes and the axon of preganglionic nerve fibers. The satellite cells thus can easily be identified. The satellite cells encapsulating the perikaryon of the ganglion cell are surrounded by a basement membrane which, in the places where this cellular sheath is interrupted, directly covers the naked surfaces of the perikaryon (Fig. 2). The nucleus of the somatic satellite cells which is hit only rarely is smaller and denser than that of the ganglion cells and is elliptical in shape. It contains a relatively large nucleolus and chromatin accumulations on the inner surface of the nuclear envelope. The cytoplasm of the somatic satellite cell contains, as seen in Figures 7 and 8, mitochondria,
cisternae of the rough surfaced endoplasmic reticulum, a large number of free ribosomes mainly aggregated into rosette-like clusters, filaments and dense bodies; they are concentrated in the paranuclear cytoplasm but are distributed also in the cytoplasmic extensions covering the neuronal perikaryon. In the present study, however, the Golgi complex and the centriole have not been encountered in the somatic satellite cells. The somatic satellite cells are closely attached to the surface of the ganglion cell and between the plasma membranes of both cells is interposed a narrow intercellular space about 200Å in width. The somatic satellite cells show in random places more or less complicated infoldings of the plasma membrane oriented parallel to the cell surface (Fig. 7), and overlappings of the thin cytoplasmic extensions are sometimes observed.

Fig. 6. The proximal portion of a dendrite (D) of a ganglion cell in the chicken pancreas. It appears more electron dense than preganglionic nerve fibers (PF) found near the perikaryon. They all are ensheathed by dark cytoplasmic sheets of peripheral satellite cells. The somewhat attenuated initial segment of the dendrite contains bundles of neurofilaments (NF), and in a slightly thickened distal segment, the Nissl substance (NS) is seen. In the connective tissue (CN) of the endoneurium, fibroblasts (FB) and perineural cells (PC) are seen, besides unmyelinated nerve fibers. Profiles of thin preganglionic nerve fibers are found on both sides of the initial segment. BM basement membrane, G Golgi complex, GV large granular vesicles in the dendrite, M mitochondria, N nucleus of a peripheral satellite cell. ×5,800

Processes of the ganglion cell

As shown in Figure 1, ganglion cells in the chicken pancreas are probably multipolar and send out several processes from the perikaryon. The initial portions of neuronal processes are seen in Figures 6 and 7. As extensions of the perikaryonal
cytoplasm, the processes contain mitochondria, Nissl substance, dense bodies, and occasionally dense-cored vesicles as well as neuro filaments and microtubules running longitudinally. The neuronal processes containing the Nissl substance should be regarded as dendrites. Cross and oblique sections of dendritic processes are frequently found in the connective tissue of the endoneurium around the perikaryon (Fig. 6, 7). They are characterized by a somewhat opaque appearance of the ground cytoplasm and richness in the Nissl substance. In this study the ramifications of the dendritic processes have not been confirmed. A neurite directly originating from the ganglion cell was not encountered in the present observation. The cytoplasmic areas of the perikaryon from which neuronal processes arose did not show any particular appearance suggesting the axon hillock. All neuronal processes are encapsulated by the thin cytoplasmic layer of the peripheral satellite cells, Schwann cells, which is continuous with the sheath of the somatic satellite cells and shows appearances similar to the latter. The outer surface of the peripheral satellite cells facing the connective tissue is covered by a basement membrane which also is continuous with that of the perikaryon. At the interruption of the satellite cell layer

Fig. 7. A part of the perikaryon and several profiles of dendrites (D). The dendrites are characterized by the electron dense cytoplasm and the Nissl substance (NS). Profiles of preganglionic nerve fibers are invested by thin, electron dense cytoplasmic extensions of satellite cell which in places are interrupted. CN connective tissue of the endoneurium, DB dense body, FB fibroblast, G Golgi complex, M mitochondria, N nucleus of a satellite cell. ×5,000
it directly covers the neuronal processes.

**Preganglionic nerve fiber**

In the pancreatic ganglion of chickens there occur an abundance of unmyelinated nerve fibers. The majority make loosely packed, well-defined bundles of unmyelinated fibers. Some of the fibers are found close to the ganglion cell bodies, either singly or grouped in small clusters. A few thin myelinated fibers are usually found sporadically among the unmyelinated nerve bundles. Each unmyelinated nerve bundle is encased by a capsule composed of several layers of the flattened cytoplasm of probable perineural cells and collagen fibrils interposed between them (Fig. 13). The unmyelinated nerve fibers are believed, for the most part, to represent preganglionic fibers and to contain partly postganglionic fibers originating from the

---

**Fig. 8.** A part of the perikaryon of a ganglion cell and the nucleated portion of a somatic satellite cell closely attached to the former. The envelope of the ganglion cell nucleus (N) shows numerous pores (†). In the perikaryonal cytoplasm abundant Nissl substance (NS), Golgi complexes (G), mitochondria (M), dense bodies (DB), multivesicular body (MB) and large granular vesicles (GV) are observed. The somatic satellite cell (SC) contains mitochondria (M), cisternae of the rough-surfaced endoplasmic reticulum and abundant free ribosomes mainly aggregated into rosettes. × 13.200
perikaryon of the intrapancreatic ganglion cells. Neither fiber, however, is discernible.

In the axoplasm of the preganglionic fibers there appear in variable numbers neurotubules, neurofilaments, smooth endoplasmic reticula (probably partial dilations of neurotubules), dense-cored or granular vesicles measuring about 1,000–1,500 Å in diameter, agranular vesicles measuring about 400–800 Å in diameter, mitochondria, and occasionally dense bodies as well as small vacuoles measuring about 1,100–1,900 Å which often appear singly or in groups (Fig. 9–13, 14–16). The neurofilaments and the neurotubules are oriented roughly parallel to the long axis of the fiber and distributed almost uniformly throughout the axoplasm intermingled with each other. As compared with the perikaryonal cytoplasm of the pancreatic ganglion cells, the

**Fig 9.** A bundle of unmyelinated preganglionic nerve fibers (PF) in the intrapancreatic ganglion of the chicken. Each axon is encapsulated by electron dense, thin cytoplasmic extensions of a peripheral satellite cell (SC) which occasionally contain glycogen particles (GP). The electron lucent axoplasm contains numerous neurotubules (NT), neurofilaments (NF), scattered mitochondria (M), large granular vesicles (GV), small agranular vesicles (AV), both of which tend to aggregate in thickened portions (†) of axons, dense bodies (DB) and small vacuoles (V). BM basement membrane, CN connective tissue. ×26,300
axoplasm of the preganglionic fibers contains conspicuously larger numbers of neurotubules, though variable from fiber to fiber (Fig. 9-16). In the longitudinal sections of neurotubules a flocculent dense material or a central dense filament

Fig 10. Cross-sections of unmyelinated and myelinated preganglionic nerve fibers found in a nerve bundle in an intraparenchymal ganglion of a chicken. Both fibers are invested by dark, thin cytoplasmic extensions of peripheral satellite cells containing closely packed parallel filaments (F) and a few mitochondria. A mesaxon (MA) is seen in the myelinated nerve fiber at the right bottom. The clear axoplasm contains numerous profiles of neurotubules (NT), neurofilaments (NF), a few mitochondria (M), large granular vesicles (GV) and elements of the agranular endoplasmic reticulum (SER). Within the neurotubules a flocculent dense filament is observed which appears in cross sections of the neurotubules as a central dense dot (†). BM basement membrane, CN connective tissue of the endoneurium. ×34,700
(Fig. 12, 14, 15) is seen within the tubular lumen. In the cross section this appears as a central dense dot (Fig. 10, 11). Irregular-shaped smooth vesicular elements which probably belong to the agranular endoplasmic reticulum are found occasionally in the axoplasm and often contain a homogeneous dense material. Findings which suggest the neurotubular origin of these smooth vesicular elements could be obtained as shown in Figures 12 and 14. The elements of the granular endoplasmic reticulum and free ribosomes were never detected in the axoplasm of the preganglionic nerve fibers. The dense-cored or granular vesicles are identical in structure and size with those found in the perikaryon of the intrapancreatic ganglion cells. The dense-cored vesicles are sporadically found in almost all profiles of the preganglionic

![Fig. 11. Cross-sections of unmyelinated nerve fibers from the preganglionic nerve bundle in the intrapancreatic ganglion of the chicken. The dark cytoplasmic sheath of a peripheral satellite cell covering the axons is interrupted and there the basement membrane (BM) bounding the satellite cell against the connective tissue (CN) directly covers the axon. Two axons in the upper part of this figure are wrapped by a double and triple layer of the cytoplasm from the peripheral satellite cell. The dark cytoplasm of the satellite cell is closely packed with parallel arrays of filaments (F). The light axoplasm contains numerous neurotubules (NT), neurofilaments (NF), mitochondria (M), agranular endoplasmic reticulum (SER), a few large granular vesicles (GV) and large vacuoles (V). Within the cross-sections of the neurotubules a central dense dot (↑) is seen. ×30,100](image)
unmyelinated fibers. As observed in Figure 9, they show a tendency to accumulate in the thickenings of preganglionic axons. In a thickening found in Figure 16 the vesicle accumulation is conspicuous, suggesting the formation of a synaptic terminal. Also the agranular vesicles measuring about 400–800 Å in diameter are gathered in the thickenings of the axon (Fig. 6). The mitochondria with rod-shaped or spherical profiles are scattered randomly in the axoplasm; the elongated ones are oriented parallel to the long axis of the axon.

The axoplasm of rare myelinated nerve fibers is provided with cytoplasmic organelles similar to those of the unmyelinated nerve fibers (Fig. 10).

Fig. 12. Longitudinal sections of unmyelinated preganglionic nerve fibers. The central thick nerve fiber is wrapped by a double or triple layer of the satellite cell cytoplasm. The light axoplasm of the nerve fiber contains numerous neurotubules (NT), less numerous neurofilaments (NF), mitochondria (M), large granular vesicles (GV), and cisternae of the agranular endoplasmic reticulum (SER). In the axoplasm there are figures which suggest the origin of the agranular endoplasmic reticulum from irregular dilatations of the neurotubules. The neurotubules contain a dense flocculent material or a dense central filament. BM basement membrane, CN connective tissue of the endoneurium, FB cytoplasmic extension of a fibroblast. ×32,300
Peripheral satellite cell (Schwann's cell)

Each unmyelinated and rare thin myelinated fiber of nerve bundles is enveloped by a thin cytoplasmic layer (or layers) of peripheral satellite cells (Schwann cells) associated with a basement membrane. As shown in Figure 13, thin cytoplasmic extensions of a Schwann cell enfolding a large number of axons are each electron opaque, so that they are easily distinguished from electron lucent axons. Between two closely adjacent axons a single thin cytoplasmic sheet is interposed (Fig. 10, 13). The oval nucleus of the peripheral satellite cell is rarely found in the nerve bundle and appears electron opaque (Fig. 13). The cytoplasm contains a Golgi complex, a centriole (Fig. 16), mitochondria, dense bodies similar to those of the perikaryon of unmyelinated preganglionic nerve fibers. The axons of variable thickness are individually ensheathed by dark, thin cytoplasmic extensions of peripheral satellite cells. At the interrupted portions of the satellite cell sheath the basement membrane (BM) directly covers the naked areas of the axons. A dense nucleus (N) of the peripheral satellite cell is seen. The axoplasm contains neurotubules, neurofilaments, large granular vesicles and mitochondria (M). At the left bottom profiles of probable dendrites (D) containing Nissl substance are seen. Around this nerve bundle a capsule composed of perineural cells (PC) alternating with connective tissue layers (CN) is present. EA acinar cell of the pancreas. ×5,800
ganglion cells (Fig. 15), cisternae of the granular endoplasmic reticulum and free ribosomes (Fig. 15, 16). The cisternae are sometimes dilated and contain a finely granular electron dense material (Fig. 14). A conspicuous parallel array of closely packed cytoplasmic filaments is seen in the cytoplasm (Fig. 10, 11, 15). The glycogen particles are observed in random parts (Fig. 9). Among the cell organelles only the Golgi complex, centriole and dense bodies are restricted to the perinuclear cytoplasm, whereas, others, especially mitochondria, are distributed also in the cytoplasmic extensions. The cytoplasmic coverings of unmyelinated axons by peripheral satellite cells are not completely continuous, showing in random places more or less

Fig. 14. A longitudinal section of an unmyelinated preganglionic nerve fiber wrapped by the nucleus-containing portion of a peripheral satellite cell. Near the nucleus (N) a dilated cisterna of the granular endoplasmic reticulum (ER) filled with a dark finely granular material, free ribosomes and an elongated mitochondrion (M) are seen. In the axoplasm there occur many neurotubules (NT) filled with a dense flocculent material, neurofilaments (NF), large granular vesicle (GV) and cisternae of the agranular endoplasmic reticulum (SER) which probably originate from irregularly dilated portions of the neurotubules. BM basement membrane, CN connective tissue of the endoneurium containing collagen fibrils. × 25,500
Fig. 15 and 16. A nucleus (N)-containing part of the peripheral satellite cell. In the electron dense perinuclear cytoplasm there occur mitochondria (M), parallel arrays of filaments (F), free ribosomes (R), a centriole (C), a Golgi complex (G) and dense bodies (DB) similar to those found in the perikaryon of the ganglion cell. The thin cytoplasmic extensions of satellite cells wrap many axons (PF) of preganglionic nerve fibers. The axoplasm contains neurotubules, neurofilaments, mitochondria (M), glycogen particles (GP) and large granular vesicles (GV). At the bottom of Figure 16 a thickened portion of an axon shows an accumulation of large granular vesicles. BM basement membrane. Fig. 15: ×26,300; Fig. 16 ×33,500
extensive interruptions or gaps (Fig. 10, 13, 15) where axons are to some extent naked, being covered directly by the basement membrane. On the contrary, two or three folded overlappings of thin cytoplasmic layers of the peripheral satellite cell occasionally wrap the unmyelinated axons. In Figures 11 and 13 a cross section and in Figure 12 a longitudinal section of such nerve fibers are seen. In the satellite cell cytoplasm covering the thin myelinated nerve fibers a mesaxon is often seen (Fig. 10).

**Axo-somatic synapse**

Along the surface of the intrapancreatic ganglion cells, profiles of many unmyelinated preganglionic nerve fibers with different diameters are found as shown in Figure 17. A synaptic terminal (ST) and several axons (PF) of preganglionic nerve fibers on the surface of a perikaryon (PK). They are wrapped by thin cytoplasmic sheets of the peripheral satellite cell (SC). The synaptic terminal lying in a concavity of the perikaryon contains abundant agranular synaptic vesicles of varying shape, a mitochondrion (M) and a few glycogen particles (GP), and it is separated from the perikaryon by a thin cytoplasmic layer of the somatic satellite cell. The perikaryonal cytoplasm contains mitochondria (M), Nissl substance (NS), a large granular vesicle (GV), neurofilaments (NF) and neurotubules (NT). BM basement membrane, CN connective tissue, N nucleus of the peripheral satellite cell. ×28,600
in Figures 17, 19 and 23, being wrapped by peripheral satellite cell cytoplasm. Axons of such preganglionic fibers with rather small diameters contain, besides neurofilaments randomly distributed in electron lucid axoplasm, merely neurotubules and occasionally also sparse densely cored vesicles. The plasma membrane of such slender axons is for the most part separated by the thin cytoplasmic layer of the satellite cell from the perikaryon of the ganglion cell (Fig. 2, 6, 17, 23), but occasionally some axons come in direct contact with the perikaryon, the apposed plasma membranes of both constituents leaving an intercellular space 200–300 Å wide (Fig. 17, 23). These contacts should not, however, be referred to as synapses since the apposed plasma membranes show no signs of such membrane specializations as seen in the synaptic junctions. Besides these relatively slender preganglionic

![Fig. 18. A synaptic terminal (ST) with abundant agranular synaptic vesicles of varying shape, a few large granular vesicles (GV) and glycogen particles (GP). It comes in simple contact on one side with a perikaryon (PK), and on the opposite side makes a synaptic contact with a dendrite (D). In the latter contact the pre- and post-synaptic membranes are thickened and increased in density and a dense material is gathered along the synaptic membranes. The synaptic cleft contains dense granular material. In the cytoplasm of the perikaryon and dendrite there appear mitochondria (M), Nissl substance (NS), multivesicular body (MB). CN connective tissue, SC cytoplasmic sheet of satellite cell. ×28,600](image)
fibers there are frequently found axons of large diameters on the surface of the perikaryon, which undoubtedly represent widened portions or varicosities of preganglionic unmyelinated fibers. As the morphological characteristics of synaptic terminals, they contain abundant agranular synaptic vesicles (400–800 Å in diameter), granular or densely cored ones (1,000–1,500 Å in diameter), mitochondria and glycogen particles (300–350 Å in diameter). Such synaptic widenings, however, are separated from the surface plasma membrane of the perikaryon by a thin cytoplasmic sheet of the satellite cell interposed between both elements (Fig. 17, 23). A synaptic ending in Figure 18 is located in an indentation induced on the surface of the perikaryon with which it comes in direct contact. However, the juxtaposed plasma membranes of both constituents do not reveal any membrane specializations characteristic of synaptic junctions; on the opposite side this synaptic ending makes

Fig. 19. A small bundle of unmyelinated preganglionic nerve fibers near the perikaryon of a pancreatic ganglion cell. On the left border of this bundle, profiles of a dendrite (D) are present. Axons of preganglionic nerve fibers are wrapped partially with electron dense cytoplasmic extensions (SC) of the peripheral satellite cell, but some of them are naked and come in simple direct contact with each other. The same simple contacts are also seen between the dendrite and adjacent two axons, one of which contains many agranular synaptic vesicles, a mitochondrion and glycogen particles. Thus, within this nerve bundle the existence of the axo-axonal and axo-dendritic synapses is not confirmed. BM basement membrane, CN connective tissue, DB dense bodies, FB fibroblast, GP glycogen particle, GV large granular vesicle. ×25,200
a synaptic junction with a dendrite arising from the perikaryon. A similar situation is also observed in Figure 23; the surface of a synaptic thickening facing the perikaryon is isolated from the latter by a thin satellite cell cytoplasm and the

![Figure 20, 21 and 22. Three sections of the same dendrite, juxtaposed synaptic terminal (ST) and small preganglionic axon (PF), which are wrapped together by a nucleated portion of a peripheral satellite cell. The dendrite is separated into the proximal (PD) and the distal piece (DD) by an interruption. In the clear axoplasm of the synaptic terminal there are contained numerous round and elongated agranular synaptic vesicles and a few large granular vesicles, and in the dark cytoplasm of the dendrite mitochondria, dense bodies and Nissl substance are visible. In the dark cytoplasm of the peripheral satellite cell mitochondria, cisternae of the granular endoplasmic reticulum and free ribosomes are seen. In Figure 20 a synaptic junction is established between the distal piece of the dendrite and the synaptic terminal (axo-dendritic synapse), showing structural specialization in the pre- and post-synaptic membranes. In this figure the synaptic area is divided into two small areas (bi-focal), while in Figure 21 it appears uni-focal. The proximal piece and the synaptic terminal are separated by a dark cytoplasmic layer of the peripheral satellite cell. In Figure 22 the distal piece and the synaptic terminal are separated by cytoplasmic extensions of the peripheral satellite cell, and the latter comes in direct contact with the proximal piece without showing membrane specialization (simple axo-dendritic contact). BM basement membrane, CN connective tissue, FB fibroblast, N nucleus of a satellite cell, PK perikaryon of a ganglion cell. Fig. 20: × 33,500; Fig. 21: × 29,800; Fig. 22: × 25,200]
opposite surface makes a synaptic contact with a dendrite. Thus, the axo-somatic synapse could not be demonstrated in the present study. In the chicken pancreatic ganglion the occurrence of this synapse, if present, may be concluded to be very rare.

**Axo-dendritic synapse**

Contrary to the axo-somatic synapses, numerous axo-dendritic synapses are observed mainly in the vicinity of the perikaryon of ganglion cells; the axons of the preganglionic nerve fibers oriented toward the perikaryon usually approach the root portion of the dendrites and form widenings or bulbous thickenings (varicosities) which contain a large number of synaptic vesicles, and between these synaptic terminals and root portions of the dendrites there occur synaptic contacts. Figures 20, 21 and 22 respectively show different sections of the same bundle of neuronal processes invested with a nucleated portion of a peripheral satellite cell. The bundle consists of an electron lucent synaptic terminal containing numerous synaptic vesicles, a small axon of a preganglionic fiber situated in the close proximity of the nucleus and two electron dense profiles of dendritic processes containing Nissl substance and mitochondria. Probably the two dendritic elements respectively represent successive proximal and distal pieces of one and the same dendrite separated by a narrow space, and the distal piece is located near a peripheral satellite cell nucleus. These pieces presumably represent somewhat distant parts of a dendrite away from the perikaryon. In Figure 20 the synaptic terminal makes a synaptic junction with the distal piece of the dendrite. The apposed pre- and post-synaptic membranes exhibit a slight thickening and density increase and an accumulation of a dense material extends a short distance inside the pre- and post-synaptic membranes. The synaptic cleft of approximately 300 Å wide contains a finely granular material of the same electron density as the dense material inside the synaptic membranes. The synaptic site, however, is divided into two areas separated by a somewhat widened part of the synaptic cleft which appears as empty, so that it is regarded as a bifocal membrane thickening. In the other section the same synaptic site between the synaptic terminal and the distal piece of the dendrite becomes single, namely unifocal (Fig. 21). In both pictures the proximal piece of the dendrite is separated from the clear synaptic terminal by a dark thin cytoplasmic extension of the peripheral satellite cell. In another section, which is several sections apart from the one illustrated in Figure 21, the synaptic terminal comes in direct contact with the proximal piece of the dendrite without making a synaptic junction, namely “active zone,” in the juxtaposed plasma membranes (Fig. 22). In this section the distal piece of the dendrite is separated from the synaptic terminal by thin cytoplasmic extensions of the peripheral satellite cell. In Figure 23 a cluster of several profiles of preganglionic axons and a dendrite are observed in close proximity to a ganglion cell body. Among them is found a synaptic thickening of the preganglionic axon containing numerous synaptic vesicles which is separated, as mentioned above, from the ganglion cell body by a thin cytoplasmic sheet of the satellite cell, but, as revealed by the occurrence of the membrane specialization, the opposite surface of the thickening makes a synaptic contact with a dendrite characterized by containing Nissl substance and dense bodies. Near this synaptic area,
this synaptic thickening possesses a concavity which is juxtaposed to a thin axon of the preganglionic nerve fiber. This apposition of two preganglionic axons, however, proves to be a simple axon contact since no active zone is demonstrated. In Figure 24 two synaptic widenings of preganglionic nerve fibers are observed side by side containing an abundance of synaptic vesicles and mitochondria. They form synapses with two dendrites respectively which are characterized by the dense appearance of the cytoplasm and some organelles such as the Nissl substance, many neurofilaments, neurotubules and a granular vesicle (dense-cored vesicle) similar to that found in the perikaryon. In both axo-dendritic synapses, the synaptic membranes show specializations as described above, and synaptic clefts about 300 Å wide contain a dense, finely granular material. The other surfaces of these synaptic widenings are invested with the dense cytoplasm of the peripheral satellite cell containing ribosomes and a few glycogen particles.

Fig. 23. A cluster of several profiles of preganglionic axons (PF), a synaptic terminal (ST) and a dendrite (D) found near a ganglion cell body (PK). Some of them are separated from each other by electron dense cytoplasmic layers (SC) of the satellite cell. A synaptic ending containing numerous small agranular vesicles, some large granular vesicles and glycogen particles is in contact with a dendrite but it is separated by a thin electron opaque cytoplasmic layer of the satellite cell from the ganglion cell body. A small preganglionic axon near the left bottom comes in simple direct contact with the ganglion cell body. BM basement membrane, CN connective tissue, DB dense body, M mitochondria, NS Nissl substance. \( \times 33,500 \)
A synaptic terminal of the preganglionic nerve fiber illustrated in Figure 18 is located in a concave hollow induced on the surface of the perikaryon of a ganglion cell where it borders directly on the perikaryon without showing any characteristics of the synaptic junction. On the opposite surface, this synaptic widening comes in synaptic contact with a root portion of a dendrite protruding from the same perikaryon. In this axo-dendritic synapse, the membrane thickening, the accumulation of a dense material along the postsynaptic membrane and the synaptic cleft filled with a finely granular material are conspicuous. In the postsynaptic area of the dendrite, a multivesicular body is observed between the mitochondria and Nissl substance. In Figure 26, two synaptic terminals of preganglionic fibers containing abundant synaptic vesicles, mitochondria and glycogen particles are found side by side in close contact, but the apposed plasma membranes of the synaptic terminals do not show any specialized areas characteristic of the synaptic membranes. A similar simple contact is also observed between one of these synaptic terminals and a small axon of the preganglionic nerve fiber adjacent to the right side.

A voluminous synaptic terminal of the preganglionic nerve fiber is illustrated in Figure 25, being filled with an abundance of synaptic vesicles and mitochondria. This terminal is almost entirely encapsulated by electron opaque thin cytoplasmic extensions of the peripheral satellite cell and isolated from surrounding neuronal processes, most of which are thought, on account of containing considerable amount
of ribosomes and elements of the rough-surfaced endoplasmic reticulum, to be dendrites protruding probably from the neighboring ganglion cell body. Although the synaptic cleft is only partly visible, only on one side this terminal forms a synaptic junction with one of the dendrites where the apposed plasma membranes of the terminal and the dendrite show the thickening and density increase associated with the accumulation of an electron dense material along the plasma membranes.

Fig. 25. A voluminous synaptic terminal (ST) of a preganglionic nerve fiber surrounded by dendrites (D). Electron dense cytoplasmic layers (SC) of a peripheral satellite cell intervene between both elements. Only the naked, upper portion of the terminal is in synaptic contact with a dendrite. The terminal is filled with abundant, closely packed small agranular synaptic vesicles of varying shape, less numerous large granular vesicles with a dense central core and a few mitochondria. BM basement membrane, CN connective tissue, D dendrite, FB fibroblast, PF axon of the preganglionic nerve fiber, PK perikaryon. ×25,200

Synaptic terminal and synaptic vesicles

Bulbous synaptic endings of the preganglionic nerve fibers generally appear electron lucent and show profiles of variable shapes and sizes (Fig. 16–18, 20–26). In the synaptic terminals few neurofilaments and neurotubules are identified.
They always contain abundant membrane-bound synaptic vesicles more or less closely distributed throughout the terminal axoplasm. Synaptic vesicles of preganglionic nerve fibers of the intrapancreatic ganglion of chickens are classified into two types: agranular and granular vesicles. The agranular vesicles measuring 400–800 Å in diameter are round or oval in shape and contain only a homogeneous material which is somewhat more electron dense than the light axoplasmic matrix.

Fig. 26. A cluster of two synaptic terminals (ST), dendrites (D) and preganglionic axons (PF) in the proximity of a perikaryon (PK). They are partially wrapped by the cytoplasmic layers (SC) of satellite cells. Two synaptic terminals of preganglionic axons containing abundant small agranular, a few large granular vesicles, glycogen particles and mitochondria lie closely side by side without showing any signs of membrane specialization. The upper synaptic terminal comes in simple direct contact with a preganglionic axon adjacent on the right side. BM basement membrane, CN connective tissue, FB fibroblast. × 9,200

Among the round or oval forms there occur more or less elongated or tubular ones in almost all terminals. The numerical ratio of elongated forms differs from terminal to terminal. In the terminals illustrated in Figures 24, 25 and 26 the round and oval vesicles predominate but in the terminal illustrated in Figures 20 and 21 the elongated ones predominate. At any rate, this mixed population of different
forms of synaptic vesicles is common in almost all synaptic endings of the pre-ganglionic fibers in the chicken intrapancreatic ganglion.

The granular or dense-cored vesicles measuring 1,000–1,500 Å in diameter are conspicuously larger than the agranular vesicles though they are variable in size from vesicle to vesicle. They contain an electron dense, round central core whose electron density can vary to a large extent. This type of vesicles corresponds to the large granular vesicles described by the previous authors (Fig. 23–25). The number of the large granular vesicles contained in a synaptic terminal is strongly variable though it is generally small as compared with that of the agranular vesicles. A terminal which contains no granular vesicle is rare (Fig. 17, 26). Large granular vesicles found in synaptic widenings should be identical with those found in the perikaryon of the intrapancreatic ganglion cell, in the dendrites originating from the perikaryon and in the axons of preganglionic nerve fibers since the granular vesicles found in these various locations are almost completely identical with each other in their fine structure and size. Though they are scattered in a small number in the above mentioned locations, they are more or less concentrated in the synaptic endings. In the synaptic terminals of preganglionic nerve fibers in the intrapancreatic ganglion of the chicken, the so-called small granular or dense-cored vesicles have never been demonstrated. Besides the synaptic vesicles mentioned above, most synaptic terminals possess a small number of mitochondria and glycogen particles measuring 300–350 Å in diameter (Fig. 17, 18, 20–23, 26). These two constituents, however, are frequently missing in the synaptic terminal.

**Discussion**

As mentioned in the Introduction the existence of the ganglion along the paths of the nerves in the pancreatic tissue of vertebrates has long been known by light microscopy. Electron microscopic observations on the intrapancreatic autonomic ganglion, however, have been carried out only by two authors; RHODIN (1963) reported on the pancreatic ganglion in the cat and WATARI (1968) in the bat and monkey, but the observations of both authors were mostly restricted to the perikaryon of the ganglion cell and the bundles of unmyelinated nerve fibers running through the ganglion. The chief purpose of WATARI's observation was to study the synaptic endings of the autonomic nerve fibers in exocrine and endocrine pancreas. An electron microscopic study of similar purpose has been recently carried out also by KOBAYASHI and FUJITA (1969) in the pancreas of the dog, guinea pig and pigeon. Neither of these authors described the fine structure of the interneuronal connection to pancreatic ganglia which is one of the essential subjects in the present study.

As known in the autonomic ganglia in several animal species, the intrapancreatic ganglion cells of chickens contain in their perikaryon mitochondria, Golgi complexes distributed at various sites around the nucleus, Nissl substance, numerous neurofilaments about 100 Å in thickness, less numerous neurotubules measuring about 250–290 Å in diameter, granular or dense-cored vesicles, dense bodies (probable lysosomes) and occasionally multivesicular bodies. In the present study the centriole in the ganglion cell has not been encountered as was demonstrated only by FORSS-MANN (1964) in the ganglion cell of the superior cervical ganglion of the rat. Glycogen particles have not been demonstrated in the perikaryon of the chicken
intrapancreatic neurons, although they were discovered in a large amount by Yamamoto (1963) in the abdominal sympathetic ganglion cells of the bullfrog and recently observed by Colborn and Adamo (1969) in the lizard stellate ganglion. Seife (1969a, b) also demonstrated the glycogen particles exhibiting configuration “corps glycogenique” in the perikarya of neurons of several sympathetic ganglia of certain mammals.

The important biological evidence that Nissl substance is nothing but the rough-surfaced or granular endoplasmic reticulum associated with free ribosomes has been electron microscopically revealed by Palay and Palade (1955). In the neurons of the chicken intrapancreatic ganglion the Nissl substance consists of flattened cisternae studded by ribosomes which ramify and anastomose into an irregular reticulum and of abundant free ribosomes mostly aggregated into rosette-like clusters closely associated with the reticulum. Most authors engaged in the study of the autonomic neurons confirmed a similar diffuse distribution of Nissl substance throughout the perikaryonal cytoplasm, but some investigators suggested the existence of Nissl bodies (Nissl-Schollen); thus Pick, de Lemos and Gerdin (1964), in human sympathetic neurons, and de Lemos and Pick (1966), in the neurons of rat thoracic ganglia, recognized Nissl substance conglomerated into Nissl bodies. Cravioto (1962) confirmed in human sympathetic ganglia the occurrence of two types: the more diffuse Nissl substance and the less diffuse Nissl body. Pick (1963) observed that in the neurons of the frog sympathetic ganglion the distribution of the granular endoplasmic reticulum, referred to as Nissl substance, was diffuse. According to Rhodin (1963) the Nissl substance is rarely gathered in stacks (true Nissl bodies) in the neuron of the cat pancreatic ganglion. As some investigators of autonomic ganglion cells noted (De Lorenzo, 1960; Forssmann, 1964; Wechsler and Schmekel, 1967; de Lemos and Pick, 1966; Yoshida, 1968) also in the Nissl substance of the neurons of the chicken intrapancreatic ganglion the free ribosomes associated with the granular endoplasmic reticulum are abundant in contrast with the paucity of membrane-studded ribosomes. However, the “areticular” Nissl substance (complex of clusters of ribosomes not associated with endoplasmic reticulum) observed by Colborn and Adamo (1969) in the neuron of the lizard stellate ganglion has not been confirmed. In the perikaryon of the chicken intrapancreatic neuron, cisternae of the granular endoplasmic reticulum (Nissl substance) contain electron dense homogeneous material but they show no conspicuous dilatations.

The most interesting and constant cytoplasmic structures of the perikaryon of the intrapancreatic ganglion cells of the chicken are granular or dense cored vesicles, 1,000–1,500 Å in diameter. That they occur rather concentrated in the proximity of Golgi complexes suggests that they might probably be elaborated in the Golgi complexes. Similar dense-cored vesicles were demonstrated by many authors in various autonomic ganglia especially in sympathetic ones, and their possible formation in the Golgi complex was suggested (Cravioto, 1962; Unsicker, 1967; Wechsler and Schmekel, 1967; Becker, 1968; Elfvin, 1968; Watari, 1968; Yoshida, 1968; Colborn and Adamo, 1969, etc.).

In the central nervous system the occurrence of granular vesicles in the perikarya of neurons was revealed by some authors; in the tuber cinereum of Xenopus laevis, Peute (1968) demonstrated granular vesicles of 1,000–1,300 Å in diameter.
elaborated probably in Golgi cisternae, and SUBURO and DE IRALDI (1969) observed in the rat's supraoptic nucleus granulated vesicles of about 500–2,500 Å in diameter. PEUTE (1968) suggested in a combined electron and fluorescence microscope study that these vesicles contain biogenic amine.

Here it comes into question whether similar cored vesicles occur also in the perikarya of the neurons of parasympathetic ganglia. DIXON (1966) and YOSHIDA (1968) revealed in the perikarya of the parasympathetic neurons of the rabbit ganglion oticum and in those of the ganglion oticum, pterygopalatinum and ciliare of the hamster, cored vesicles of 400–800 Å in diameter and assumed that they might be elaborated in the perikaryon and transported into the axon to be accumulated in nerve endings. HUIKURI (1969) confirmed similar findings in the rat ciliary ganglion and observed two types of cored vesicles; one type was 900–1,200 Å in diameter and was identified with the granular vesicle in the nerve terminal, and the other type was much larger, measuring about 2,000 Å or more in diameter, and diagnosed as the neurosecretory granule. In contrast with the above mentioned investigators, DE LORENZO (1960), in a study on ciliary ganglia of chick embryo and newly hatched chicks, TAKAHASHI and HAMA (1965a) and TAKAHASHI (1967), in a study on chick ciliary ganglia, reported the absence of the cored vesicles or made no description of them. Therefore, concerning the occurrence of cored vesicles in parasympathetic ganglia there is divergency in the opinions of some authors. As to the cored vesicles found in perikarya of sympathetic neurons, their dimensions differed in various sympathetic ganglia and in various animal species, and in some ganglia the occurrence of two types of cored vesicles, larger and smaller ones, was reported. The nature and the functional significance of the dense-cored vesicles are controversial as discussed below.

In the light microscopic observations on the autonomic ganglion cells in human and rat intestinal wall (ITO, 1936; ITO and NAGAHIRO, 1937; ITO and KUBO, 1940) and in the submandibular gland of the dog (ITO and AOIKI, 1939) the eccentric location of the nucleus in the perikaryon was emphasized as an important morphological characteristic of the autonomic neuron. In electron microscopic studies on autonomic ganglia this characteristic was suggested by some investigators (RHODIN, 1963 in cat pancreatic ganglion, COLBORN and ADAMO, 1969 in lizard stellate ganglion). The eccentric location of the nucleus has been conspicuous also in the chicken intrapancreatic neurons.

Concerning the nucleus of the sympathetic and parasympathetic neuron, richness in nuclear pores has been noticed by many investigators (CRAVIOTO, 1962; FORSSMANN, 1964; TAKAHASHI and HAMA, 1965b; UNSICKER, 1967; BECKER, 1968; YOSHIDA, 1968; COLBORN and ADAMO, 1969). TAKAHASHI and HAMA (1965b) calculated the number of nuclear pores in the tangential sections of the nuclear envelope of neurons in the chicken ciliary ganglion. In the chicken intrapancreatic neuron nuclear pores measuring about 600–800 Å in diameter have been demonstrated in large numbers, and in tangential sections they exhibited round profiles with a central dot, which was observed also by CRAVIOTO (1962), UNSICKER (1967) and COLBORN and ADAMO (1969) in several autonomic neurons of certain animal species.

The occurrence of a rod-shaped nuclear inclusion body was already demonstrated in autonomic neurons by light microscopy (HOLMGREN, 1899; ITO and
NAGAHIRO, 1937). Recently, SIEGESMUND, DUTTA and Fox (1964) confirmed the presence of rod-shaped nuclear inclusions by light microscopy in extraglomerular granule cells of the olfactory bulb of squirrel monkey and rabbit, in rabbit cerebellar granule cells and medium and small sized pyramidal cells, and they clarified by electron microscopy that they consist of a compact bundle of fibrils 50–70Å in diameter. Moreover, SEITE (1969b) observed microfibrillar paracrystalline inclusions in the perikaryonal cytoplasm, axon as well as dendrite and “crystalloide microtubulaire” in the nucleus of the neurons of several sympathetic ganglia in the cat, rat and mouse. According to him the crystalloids in the cytoplasm and nucleoplasm are different. In the present study it has been revealed that similar spindle- or rod-shaped inclusion bodies with unknown length occur occasionally near the center of the nucleus and they consist of a bundle of densely packed parallel filaments or fine fibrils. This paracrystalline fibrillar structure has never been found in the perikaryonal cytoplasm in the chicken intrapancreatic ganglion.

As has been established in the autonomic ganglion cells of other animals, the neurons of the chicken intrapancreatic ganglia were shown to be multipolar for the most part. Difficulties in differentiating dendrites from the axon were emphasized by some authors like ELFVIN (1963a) and de LEMOS and PICK (1966). ELFVIN (1963a) and YAMAMOTO (1963) used the term “cell processes” and “nerve processes” respectively to avoid the application of dendrite and neurite or axon though it was postulated by some authors that the multipolar perikarya of autonomic neurons possess a varying number of dendrites and only one axon (ELFVIN, 1963a; RHODIN, 1963). FORSSMANN (1964) observed in his electron microscopic study on rat superior cervical ganglia that numerous neuronal processes all had the same ultrastructural appearances, containing the Nissl substance even in their portions considerably distant from the perikarya. ELFVIN (1963a) revealed in his study on cat superior cervical ganglia the presence of Nissl substance in a portion of neuronal processes near the perikaryon. Further, de LEMOS and PICK (1966) suggested in the study on rat thoracic ganglia that dendrites and axons were not discernible by the presence or absence of Nissl substance. Contrary to these authors, CRAVIOTO (1962) offered, in his study on the ganglia of the human sympathetic trunk, an opinion that the ribosomes enter from the perikaryon into dendrites but not into neurites. RHODIN (1963) illustrated, in a short observation on the cat pancreatic ganglion cell, dendrites containing Nissl substance associated with free ribosomes. In their study on lizard stellate ganglia COLBORN and ADAMO (1969) recently classified neuronal processes of multipolar neurons into dendrites and neurites on the basis of their content of cell organelles; according to them dendrites contain Nissl substance and free ribosomes in an appreciable amount, while neurites contain many neurofilaments and neurotubules and few or no ribosomes. The same criteria of neuronal processes were used in the present study on chicken intrapancreatic ganglia. The neuronal processes to be regarded as dendrites appear electron opaque and contain, besides Nissl substance and ribosomes as observed by ELFVIN (1963a), mitochondria, dense bodies, neurofilaments, neurotubules, and occasionally dense-cored vesicles and rarely a multivesicular body, all of which are identical with those found in the perikaryon. Thus, the dendrites which are found in a considerable number around the perikaryon are nothing but the cytoplasmic prolongations of the latter.
In the present study neuronal processes which appeared closely around and protruded from the perikarya of the intrapancreatic ganglion cell and which are to be considered as neurites in ultrastructure have never been encountered.

The occurrence of an axon hillock of the neurite in autonomic neurons was suggested by some authors; in neurons of the human sympathetic trunk the axon hillock forms a large area of the perikaryonal cytoplasm lacking in ribosomes (Cravioto, 1962), and in neurons of hamster sympathetic ganglia the axon hillock is a cytoplasmic area lacking ergastoplasm but containing a small amount of free ribosomes (Yoshida, 1968). The corresponding cytoplasmic area has not been demonstrated in the perikaryonal cytoplasm of the chicken intrapancreatic ganglion cell.

The majority of unmyelinated nerve fibers contained in chicken intrapancreatic ganglia make well-defined, large nerve bundles which are, as revealed Watari (1968) in the pancreatic ganglia of the monkey and bat, enveloped by a capsule composed of several layers of the electron dense flattened cytoplasm of probable perineurial cells which alternate with connective tissue layers composed of collagen fibrils (see also Elfvin, 1963a; Forssmann, 1964; Thomas and Jones, 1967; O’Daly and Imaeda, 1969). Unmyelinated nerve fibers found in autonomic ganglia may mostly be preganglionic fibers except for postganglionic ones (axons) protruding from the perikarya of the neurons of ganglia. In the chicken intrapancreatic ganglion, differentiation between pre- and post-ganglionic fibers is difficult as suggested by Becker (1968) in the study on rat uterine cervical ganglion. On the contrary, Elfvin (1963a) classified unmyelinated nerve fibers in the cat superior cervical ganglion into dense and light fibers, and took the former characterized by close packing of thick filaments (neurotubules) for nerve cell processes and the latter for preganglionic fibers. The nerve cell processes designated by Elfvin may possibly be dendrites protruding from local ganglion cell bodies and do not seem to be postganglionic axons or neurites. In the present study dendrites of chicken intrapancreatic ganglion cells, if not continuous with the perikaryon, are easily distinguished from the preganglionic nerve fibers on account of the electron dense appearance of the ground cytoplasm, the appreciable amount of Nissl substance (ergastoplasm) and free ribosomes as described above.

The ultrastructure of unmeylinated, for the most part preganglionic, nerve fibers in autonomic ganglia has been discussed by many investigators (De Lorenzo, 1960; Elfvin 1963a, b; De Lemos and Pick, 1966; Unsicker, 1967; Becker 1968; Watari, 1968). The electron lucent axoplasm of preganglionic unmyelinated nerve fibers in the intrapancreatic ganglion of the chicken contains neurofilaments and neurotubules, smooth endoplasmic reticulum, cored or granular vesicles (1,000–1,500 Å in diameter), agranular vesicles (400–800 Å in diameter), scattered mitochondria, and occasionally dense bodies and vacuoles of about 1,100–1,900 Å in diameter which often appear singly or in groups. Most of these axoplasmic organelles have been observed also by the above cited authors in several autonomic ganglia of various animal species. The occurrence of the agranular endoplasmic reticulum has been reported by Becker (1968) in the study on the rat uterine cervical ganglion. In the present study it has been found that agranular endoplasmic reticula may probably be formed by irregular dilatations of neurotubules. The occurrence of cored or granular vesicles in the axoplasm was reported by several authors;
Elfvin (1963b) noted the presence of larger vesicles (700–1,000 Å in diameter) with an oval or round dense core in the axoplasm of preganglionic fibers of the cat superior cervical ganglion. Unsicker (1967) observed, also in the axoplasm of preganglionic nerve fibers found in the ganglion of the hamster adrenal medulla, similar cored vesicles of less than 1,200 Å in diameter resembling the neurosecretory elementary granules. Recently Watari (1968) found, in the axons of the monkey and bat pancreatic ganglia, large cored vesicles which are similar in structure and dimensions to those in the perikarya of intrapancreatic ganglion cells. Sparse large cored vesicles observed in almost all axons of preganglionic fibers of the chicken intrapancreatic ganglion agree in ultrastructure and dimensions with those found in their perikarya. As described above, among the authors who revealed large granular vesicles in the perikarya of autonomic ganglion cells there were those who supposed that the vesicles might be transported from perikarya via axons to synaptic endings (Elfvin 1963; Unsicker, 1967; Wechsler and Schmekel, 1967; Watari, 1968). Small agranular vesicles (400–800 Å in diameter) found in the axoplasm of preganglionic fibers of the chicken intrapancreatic ganglion may possibly also correspond to those observed by Watari (1968) in axons of unmyelinated fibers in monkey and bat pancreatic ganglia.

In electron microscopic studies on peripheral autonomic ganglia in various animal species, satellite cells and Schwann cells which invest the perikaryon and neuronal processes have been observed by many authors. As proposed by Rhodin (1963) and Watari (1968), satellite cells encapsulating the perikaryon and Schwann cells enfolding the nerve fibers are believed functionally and structurally equivalent with each other. Several authors designated the cells with differentiated terms, "somatic" and "peripheral" satellite cell (Forssmann, 1964; Unsicker, 1967; Becker, 1968), but others merely with a single name such as "satellite cell" (Cravioto, 1962; Elfvin, 1963a), or Schwann cell (De Lorenzo, 1960). The identity of the somatic and peripheral satellite cells has been proved in the present study on chicken intrapancreatic ganglion, and it has been pointed out as a remarkable characteristic of both elements that their nucleus and the cytoplasm are conspicuously more electron dense than those of ganglion cells. The satellite cell sheaths are thus easily differentiated from the neuronal elements. Such electron opaque satellite cells have not been observed by any authors who mostly reported or illustrated a clear satellite cell covering (Elfvin, 1963a; Rhodin, 1963; Takahashi and Hama, 1965b; Unsicker, 1967); a sole exception was Becker (1968) who remarked on the somewhat electron dense ground cytoplasm of satellite cells in the rat uterine cervical ganglion.

The satellite cells envelope the perikaryon and cell processes as well as preganglionic axons as thin cytoplasmic sheets, but these are interrupted in places where the neuronal elements are directly covered by the basement membrane (Colborn and Adamo, 1969). Such gaps in the satellite cell investment were frequently encountered in the chicken intrapancreatic ganglion. Overlapping of the cytoplasmic sheets of satellite cells are also not rare. Especially in the peripheral satellite cells the two or three folded overlappings of thin cytoplasmic layers wrapping an axon were occasionally found, showing a configuration similar to that of the "tunicated nerve fiber" (Edwards, Ruska and de Harven, 1958; Forssmann, 1964; Becker, 1968). The formation of a loose myelin sheath investing the perikaryon,
as revealed by Hess (1965) and Takahashi and Hama (1965a, b) in the ciliary ganglion, has not been confirmed in the chicken intrapancreatic ganglion. The nuclei of satellite cells were only rarely found in the chicken intrapancreatic ganglion. It is, therefore, conjecturable that perikarya of chicken intrapancreatic ganglion cells may be enveloped by a few somatic satellite cells. Unsicker (1967) postulated in his study on the ganglion in the hamster adrenal medulla that every ganglion cell might be ensheathed by individual satellite cell sheath derived from several satellite cells.

It has been revealed in various tissues (Honjin, Takahashi and Tasaki, 1965; Jabonero, 1967; Umahara, 1968; Watari, 1968), that unmyelinated nerve fibers show beaded swellings or varicosities, containing synaptic vesicles and making synaptic contacts with effector cells. The same structure was confirmed by Elfvin (1963a, b) in the interneuronal connections present in superior cervical ganglia of the cat. In chicken intrapancreatic ganglia, probable synaptic terminals were represented by thickenings of axons of preganglionic unmyelinated nerve fibers containing synaptic vesicles.

Concerning interneuronal synapses in autonomic ganglia of various animal species numerous ultrastructural studies have been carried out by many investigators (Barton, 1957; Taxi, 1957; Causey and Barton, 1958; de Lorenzo, 1960; Cravioto, 1962; Grillo and Palay, 1962; Elfvin 1963a, b; Pick, 1963; Yamamoto, 1963; Hess, 1965; Forssmann, 1964; Pick, de Lemos and Gerdin, 1964; Szentagothai, 1964; Takahashi and Hama, 1965a; de Lemos and Pick, 1966; Wechsler and Schmekel, 1967; Takahashi, 1967; Unsicker, 1967; Becker, 1968; Watari, 1968; Yoshida, 1968; Colborn and Adamo, 1969; Huikuri, 1969). In autonomic ganglia the existence of axo-somatic, axo-dendritic and axo-axonal synapses has been proposed by the authors mentioned above. Dendro-dendritic synapses, however, were observed only by Barton (1957) in the superior cervical ganglion. Also a few investigators described the presence of axo-axonal synapses (Forssmann, 1964; de Lemos and Pick, 1966; Colborn and Adamo, 1969). Thus, the common interneuronal synapse types found in autonomic ganglia of several animal species are axo-somatic and axo-dendritic synapses. The ciliary ganglia of the chicken are particular in this regard since they possess merely peculiar axo-somatic synapses, the so-called “calyciform synapses” (de Lorenzo, 1960; Hess, 1965; Takahashi and Hama, 1965a, b; Takahashi, 1967).

In other autonomic ganglia it has been shown by many authors that axo-dendritic synapses are generally frequent, whereas axo-somatic ones are infrequent (Taxi, 1957; Causey and Barton, 1958; Elfvin, 1963b; Yamamoto, 1963; Forssmann, 1964; Pick, de Lemos and Gerdin, 1964; Szentagothai, 1964; de Lemos and Pick, 1966; Huikuri, 1969). This is also the case with the synapses found in chicken intrapancreatic ganglia. However, an opposite finding has been reported: that axo-somatic synapses are more numerous and axo-dendritic ones rather rare in some ganglia such as frog sympathetic ganglia (Pick, 1963), sympathetic ganglia in the hamster adrenal medulla (Unsicker, 1967) and lizard stellate ganglia (Colborn and Adamo, 1969).

In chicken intrapancreatic ganglia axo-somatic synapses have not been demonstrated clearly, but their existence should not be utterly denied since the observations in the present study have not been carried out in completely serial sections covering
a considerable thickness of the tissue. At any rate, it seems likely that in chicken intrapancreatic ganglia the occurrence of axo-somatic synapses, if present, may be very rare.

In chicken intrapancreatic ganglia numerous axo-dendritic synapses are found near the perikarya of ganglion cells; the thickened terminals of the preganglionic axons occur on dendrites at a short distance from the perikarya as revealed by Yamamoto (1963), Szentagothai (1964), Colborn and Adamo (1969) and others. The finding by Elfvin (1963b) with complete serial sections, that a preganglionic axon makes several synaptic contacts at various portions with a cell process (dendrite) has not been confirmed in this study. The existence of axo-axonal synapses, like the axo-somatic, has not clearly been revealed in the chicken intrapancreatic ganglion in spite of findings suggesting their possible existence.

In the interneuronal synapses in autonomic ganglia the specializations in the pre- and post-synaptic membranes have been observed by all investigators engaged in electron microscopic study in this research field (De Lorenzo, 1960; Elfvin, 1963b; Yamamoto, 1963; Forsmann, 1964; Takahashi and Hama, 1965a; De Lemos and Pick, 1966; Unsicker, 1967; Wechsler and Schmekel, 1967; Becker, 1968; Yoshida, 1968; Colborn and Adamo, 1969). Specializations of synaptic membranes have also been confirmed in axo-dendritic synapses of the chicken intrapancreatic ganglion. The specialized dense synaptic area corresponding to the “active zone” of Taxi (1967) usually makes a single area (uni-focal) but occasionally is divided into two smaller areas by an interruption in the membrane specialization (bi-focal). The synaptic cleft between the apposed pre- and post-synaptic membranes is about 300 Å in width in synapses found in the chicken intrapancreatic ganglion. This value is somewhat larger than that measured by the authors in several autonomic ganglia (60–200 Å), but agrees with that obtained by Takahashi and Hama (1965a) in the “synaptic complex” present in calyciform synapses of the chicken ciliary ganglion. As observed by several authors in the autonomic ganglia (Elfvin, 1963b; Takahashi and Hama, 1965a; Unsicker, 1967; Becker, 1968), the synaptic cleft found in chicken intrapancreatic ganglia is filled with a finely granular dense material. In this study simple interneuronal contacts without the formation of “active zones” have not been considered as synaptic junctions.

Concerning the synaptic vesicles contained in the presynaptic thickenings of axons, numerous observations have been reported without attaining any agreement. In the synapses found in peripheral autonomic nerve fibers innervating various tissues and organs there are seen at least three types of synaptic vesicles: 1) small agranular vesicles, 2) small granular vesicles of about the same size and 3) large granular vesicles. Richardson (1964) observed in the rabbit iris a type of nerve ending containing small agranular vesicles 200–500 Å in diameter together with occasionally large granular (cored) vesicles 800–1,000 Å in diameter and another type containing small agranular vesicles as well as a large number of small granular vesicles 200–500 Å. Richardson’s finding that the rabbit iris showed nerves and nerve endings of the first type, concluded that these are typical of cholinergic innervation. On the other hand, the dilator having nerves and nerve endings of the second type was believed to receive adrenergic innervation. Robertson (1967) also observed in the study on the innervation of the frog ultimobranchial body bulbous
endings of the axons containing three types of vesicles, large granular vesicles about 950 Å in diameter, agranular vesicles having a diameter of 450 Å and granular vesicles of the same size and he regarded these endings as characteristic of sympathetic adrenergic nerves. WATARI (1968) revealed in the synaptic terminals in the bat and monkey pancreas also three types of synaptic vesicles; small agranular vesicles 200–500 Å in diameter, small granular vesicles of about the same size and large granular vesicles 1,000–1,350 Å in diameter. He considered the synaptic terminals containing mainly the small agranular vesicles as cholinergic (parasympathetic) and those containing mainly small granular vesicles as adrenergic (sympathetic), and confirmed that the large granular vesicles can occasionally occur in a small number in both the cholinergic and the adrenergic terminals. KOBAYASHI and FUJITA (1969) demonstrated in nerve terminals found in dog pancreas three types of synaptic vesicles; small agranular vesicles 300–500 Å in diameter, small granular vesicles of the same size and large granular vesicles about 1,000–1,500 Å in diameter. On the basis of the combined occurrence of these three vesicle types they identified at least two types of nerve endings; one containing mainly the small granular vesicles and the other containing mainly the small agranular ones, and they confirmed that the large granular vesicles could occur in both types of nerve endings. In the electron microscopic study on the innervation of the human parotid and submandibular gland both of which receive a dual innervation by the sympathetic and parasympathetic nervous system, NORBERG, HÖKFELT and ENEROTH (1969) suggested that the nerve terminals of sympathetic adrenergic neurons could also be identified on the basis of their containing the small granular vesicles about 500 Å in diameter. They also showed the occurrence of large granular vesicles with a diameter of about 1,000 Å together with small granular vesicles in adrenergic terminals or neurons. Thus, they concluded that adrenergic axons contain small granular vesicles. GOSLING and DIXON (1969), who observed in the axons of the rabbit kidney numerous membrane-bounded vesicles, classified them into three types; 1) small dense-cored (granular) vesicles having diameters of 300–500 Å, 2) agranular vesicles of about the same size and 3) large granular (dense-cored) vesicles with diameters of 800–1,000 Å, and showed that 1) and 2) are by far the most common. They were of the opinion that, while the agranular and large granular vesicles have been described in both adrenergic and cholinergic nerve terminals, the small granular vesicles about 500 Å in diameter are believed to be specific to adrenergic nerve terminals. Further, they pointed out that the small granular vesicles are reduced following administration of drugs known to deplete tissue stores of noradrenalin. To sum up, it seems widely accepted that the specific synaptic vesicles for adrenergic terminals are the small granular vesicles and those for cholinergic terminals the small agranular vesicles while the nature of the large granular vesicles found in both terminals is unknown. As briefly mentioned above, experiments applying drugs to deplete tissue stores of noradrenalin have been carried out by several authors for the purpose of identifying the content of the small granular vesicles with the noradrenalin. BONDAREFF (1965), BLOOM and BARRNETT (1966), HÖKFELT (1966) and FARREL (1968) recognized that, after treatment with reserpine or α-methy-metatyrosine, the small granular vesicles in synaptic terminals exclusively were reduced in number or lost their cores, but the large granular and small agranular vesicles remained unaffected. From these
findings they concluded that the chief storage sites of noradrenalin must be the small granular vesicles.

On the other hand, previous authors, who have been engaged in the study of the peripheral sympathetic ganglia, have demonstrated only two types of synaptic vesicles: Elfvin (1963b) revealed in a study on the cat superior cervical ganglion only small agranular vesicles 300-500 Å in diameter and large granular vesicles 700-1,000 Å in diameter; de Lemos and Pick (1966), in the rat thoracic ganglia, agranular vesicles measuring 400-500 Å and a few larger granular vesicles; Unsicker (1967), in hamster sympathetic ganglia of adrenal medulla, small agranular vesicles 350-600 Å and a few large granular vesicles of 600-1,200 Å; Becker (1968), in rat uterine cervical ganglion, agranular synaptic vesicles and sparse granular vesicles of 550-1,800 Å; Hamori, Lang and Simon (1968), in cat superior cervical ganglion, usual agranular vesicles of 300-500 Å and large granular vesicles of 800-1,100 Å; and Colborn and Adamo (1969), in the lizard stellate ganglion, agranular vesicles of 500-700 Å and a few large granular vesicles of 600-1,100 Å. Also in the present study on the chicken intrapancreatic ganglion only two types of synaptic vesicles were found; namely small agranular vesicles 400-800 Å in diameter and large granular vesicles 1,000-1,500 Å in diameter. Thus, few authors have actually revealed the typical small granular vesicles known to be specific to adrenergic nerve endings. From this evidence arise three questions; the first question is whether the sympathetic ganglia are completely lacking in adrenergic nerve axons, the second is whether it is due to unsuitable fixation that no granule core was demonstrated in the small type vesicles and the third is whether, among large granular vesicles which show a wide range in diameter, those corresponding to small granular ones are mingled or not. It seems improbable that in peripheral sympathetic ganglia there exist no adrenergic preganglionic axons and endings. Machado (1967) has recently revealed that small granular vesicles in sympathetic axons of the rat pineal body increase in number after fixation with osmic acid associated with prefixation with glutaraldehyde than after fixation with osmic acid alone. In both the present study on the chicken intrapancreatic ganglion and the study on the lizard stellate ganglion carried out by Colborn and Adamo (1969), the osmic acid fixation following prefixation with glutaraldehyde has been used, but the vesicles corresponding to small granular vesicles have never been demonstrated in preganglionic axons and synaptic terminals. It is a very important finding that several authors, de LorenzO (1960), Takahashi and Hama (1965a), Takahashi (1967) and others, have not revealed the presence of large granular vesicles in the perikarya of chicken parasympathetic ciliary ganglion cells. On the other hand, there are some authors who have demonstrated granular vesicles of probable large granular type in the perikarya of parasympathetic ganglion cells; thus Yoshida (1968) found them in the hamster ganglion oticum, ciliare and pterygopalatinum, Dixon (1966) in the rabbit ganglion oticum and HuiKuri (1969) in the rat ciliary ganglion. Dixon (1966) and Yoshida (1968) were of the opinion that these granular vesicles (400-800 Å in diameter) should be of catecholamine type. HuiKuri (1969) has demonstrated similar vesicles (900-1,200 Å in diameter) also in the synaptic terminal of preganglionic axons in the rat ciliary ganglion and showed the density decrease in the core after reserpine treatment. On the basis of this evidence he came to the conclusion that these large granular
vesicles may contain catecholamine. In spite of these studies on both sympathetic and parasympathetic ganglia the nature of the large granular vesicles is still obscure. The presumption that among the large granular vesicles smaller, catecholamine-containing ones may perhaps be intermingled may not be unreasonable (Dixon, 1966; Wechsler and Schmekel, 1967; Peute, 1968; Yoshida, 1968; Huikuri, 1969). Hörfelt (1968), pointing out that the large granular vesicles seem unspecific to monoamine neurons and that they are always localized in synaptic boutons relatively far away from the synaptic cleft, suggested that they could be indirectly involved in the release of transmitter substance at the synaptic cleft. In the present study, however, findings contrary to this view have been obtained; as shown in Figure 25, large granular vesicles come occasionally in close proximity to the synaptic cleft, suggesting the possibility of their release into the latter.

Among round synaptic vesicles of small agranular type, there appear in almost all the widened synaptic terminals of preganglionic axons of the chicken intrapancreatic ganglion elongated, tubular or flattened agranular vesicles in variable numbers. Vesicles of this type were reported also by Becker (1968) in the rat uterine cervical ganglion. Since Uchizono (1965, 1967, 1968) suggested that these flattened type vesicles are characteristic of inhibitory synapses they have attracted the attention of investigators. Thereafter, however, several authors maintained that the flattening or elongation of agranular synaptic vesicles may be caused by fixation with formaldehyde or glutaraldehyde (Lund and Westrum, 1966; Walberg, 1966; Pensa and Ceccarelli, 1968; Bodian, 1970). In the present study this artifact theory cannot completely be neglected, since fixation with glutaraldehyde prior to that with osmic acid has been applied. It seems, however, doubtful that flattened or elongated agranular synaptic vesicles are all artifacts induced by glutaraldehyde fixation. Recently, Colborn and Adamo (1969) showed, in the study on lizard stellate ganglia, that the fixation with glutaraldehyde prior to osmic acid fixation caused no occurrence of elongated agranular synaptic vesicles in preganglionic axons and synaptic terminals. It seems rather reasonable to presume that the elongated synaptic vesicles may at least partially represent a stage in the course of the formation of round vesicles from neurotubules. Farrell (1968) postulated that the neurotransmitter substances which are manufactured at least partially in the cell body may be transported to the periphery by means of neurotubules, while De Iraldi and Robertis (1968) and Vollrath (1969) proposed the view that the synaptic vesicles might originate from pinching off of dilatations in the neurotubules. In the present study, as described above, it has been confirmed that small agranular synaptic vesicles also occur in the axoplasm of preganglionic nerve fibers showing a tendency to aggregate in widened portions of axons. On the basis of these findings the hypothesis on the origin of the small agranular synaptic vesicles from the neurotubules seems reasonable.

Summary

Autonomic ganglia in the chicken pancreas have been electron-microscopically investigated. They were composed of ganglion cells existing singly or making small groups and bundles of mainly unmyelinated nerve fibers.

1. The perikaryonal cytoplasm of chicken intrapancreatic ganglion cells contains
large granular vesicles 1,000–1,500 Å in diameter, dense bodies (probably lysosomes) and occasionally multivesicular bodies. The Nissl substance consisted of cisternae of endoplasmic reticulum studded by relatively sparse ribosomes and abundant free ribosomes. The nucleus of the ganglion cells located eccentrically in the perikaryon occasionally contained rod-shaped inclusion bodies consisting of a bundle of parallel filaments or fibrils.

2. The ganglion cells project their dendrites in a multipolar form, but a neurite could not be identified. The dendrites are electron dense in appearance and contain ample Nissl substance associated with free ribosomes. In addition, they contain all the organelles which could be found in the perikaryon.

3. Unmyelinated preganglionic nerve fibers make large nerve bundles mixed with a few thin myelinated nerve fibers. Their axoplasm contains large granular vesicles identical with those found in the perikarya of intrapancreatic neurons, small agranular vesicles about 400–800 Å in diameter, mitochondria and occasionally dense bodies.

4. Many axo-dendritic synapses were demonstrated, but the presence of axosomal synapse could not be proved. The existence of axo-axonal synapses was doubtful. The axo-dendritic synapses are usually found near the perikarya; the widened synaptic terminals of preganglionic fibers occur near the base of the dendrites.

5. In the axo-dendritic synapses both pre- and post-synaptic membranes are slightly thickened and show a conspicuous density increase, and a dense material is condensed beneath both membranes. The synaptic cleft (about 300 Å in width) is filled with a finely granular dense material. A “bi-focal” synaptic area, i.e., a synaptic area divided into two smaller areas by an interruption of the membrane specialization, is occasionally observed.

6. A xo-dendritic synapses contain two types of synaptic vesicles: abundant small round or oval agranular vesicles 400–800 Å in diameter and less numerous large granular vesicles 1,000–1,500 Å. The latter are identical with those found in perikarya and preganglionic axons. In the majority of the synaptic terminals there occur elongated or flattened vesicles in varying numbers, intermingling with the small round agranular vesicles.

7. The satellite cells, characterized by the high density of their cytoplasm, invest the perikaryon, dendrites and preganglionic axons with their thin cytoplasmic extensions. At interruptions of this investment the basement membrane directly covers the naked surface areas of the neuronal elements. To the contrary, preganglionic axons are sometimes wrapped by a double or triple-layered cytoplasmic sheet of peripheral satellite cells, like the so-called “tunicated nerve fibers.”

ニワトリの腎臓内自律神経節の微細構造 (内容自抄)

ニワトリの腎臓内自律神経節を電子顕微鏡で検索した。神経節の神経要素として、単独であるいは小集団で現われる神経細胞と主に無髓の神経線維束とがある。

1. 神経細胞の細胞質には大有蚔体（直径 1,000〜1,500 Å）、暗調顆粒（おそらくライソーム）および時折り多胞体が含まれる。ニッスル物質は相対的にリボソームの付着
の少ない粗面小胞体と多数の遊離リポソームからなる。神経細胞の核は偏在し、時折り密に並行した微原線維からなる棒状の封入体を含む。

2. 神経細胞は多極性で、少数の樹突状起を備えるが、軸索突起は確認できなかった。樹突状起は多量のミルス物質、遊離のリポソームおよびその他ほとんどすべての胞体内細胞質要因を含む。

3. 節前無髄神経線維は太い神経線維束形成するが、その中に数本の細い有髄神経線維も含む。軸索形質には胞体内のものと同様の大有芯胞（直径400～800Å）、余粒体および時折り暗調顆粒を含む。

4. 軸索-樹突状起終末部は多いが、軸索-胞体終末部は立証できなかった。また軸索-軸索終末部の存在も疑わしかった。軸索-樹突状起終末部は神経細胞体の近く、とくに樹突状起の根元近くにみられる。

5. 軸索突-樹突状起終末部ではシナプス前膜および後膜に軽微な肥厚や著しい電子密度の増大がある。また両膜の内側に沿って、暗調の物質がある。シナプス裂腔 synaptic cleft（幅約300Å）は暗調の微細顆粒状物質で満たされる。またシナプス域の膜分化が中段して二つの小域に分けられたいわゆるbi-focal synaptic areaがしばしば見られる。

6. 軸索-樹突状起終末部には円形ないし卵形の無芯小胞（直径400～800Å）と大有芯胞（直径1,000～1,500Å）が含まれる。その大多数の終末部には長梢円形の小胞も種々の数で見られる。

7. 外套細胞質は電子密度が高く、神経細胞体、樹突状起および節前軸索を被う。外套細胞の薄い細胞質層による外被のないところでは基底膜が直接神経要素を被う。また節前軸索が末梢神経の外套細胞（シュヴァン細胞）の薄い二重ないし三重の細胞質層によって被われたいわゆるtunicated nerve fibersが時々見られる。

References


———: The ultrastructure of the superior cervical sympathetic ganglion of the cat. II. The fine structure of the preganglionic end fibers and the synapses as studied by serial sections. J. Ultrastr. Res. 8: 441–476 (1963b).


———: In vitro studies on central and peripheral monoamine neurons at the ultrastructural level. Z. Zellforsch. 91: 1–74 (1968).


Huikuri, K.: Electron microscopic observations on the granular vesicles in the ciliary ganglion of
Ganglion in the Chicken Pancreas 495


Ruska, H. und C. Ruska: Licht- und Electronenmikroskopie des peripheren neurovegetativen


Takahashi, K.: Special somatic spine synapses in the ciliary ganglion of the chick. Z. Zellforsch. 83: 70–75 (1967).

Takahashi, K. and K. Hama: Some observations on the fine structure of the synaptic area in the ciliary ganglion of the chick. Z. Zellforsch. 67: 174–184 (1965a).

———: Some observations on the fine structure of nerve cell bodies and their satellite cells in the ciliary ganglion of the chick. Z. Zellforsch. 67: 835–843 (1965b).


Ganglion in the Chicken Pancreas


工藤重治
〒371 前橋市昭和町
群馬大学医学部
第一解剖学教室

Dr. Shigeharu Kudo
Department of Anatomy
Gunma University School of Medicine
371 Gunma, Japan