MORPHOLOGICAL EVIDENCE FOR DOUBLE INNERVATION OF NEURONS OF PERIPHERAL GANGLIA

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In earlier publications [2, 3, 4], reporting results of our investigations and evidence from the literature, it was indicated that neurons of peripheral ganglia of the vegetative nervous system make synaptic connection not only with centrally originating preganglionic nerve cells, but also with axons of peripheral sensory neurons. In other words, peripheral ganglia are not only cross-over points for impulses, following the activity of the central nervous system, but also peripheral reflex centers.

It is important to examine the topographical relations of synaptic formations of preganglionic cells and axons of peripheral sensory neurons.

In one of the cited works [2] it was shown that section of N. intestinalis results in degeneration of ascending axons of Dogiel type II cells in the central regions of these nerves, and degeneration of the pericellular networks formed by them in the solar plexus. In addition it was shown that on individual neurons it is possible to detect degenerating pericellular networks and intact synaptic boutons. A similar observation is also reported by I. A. Chervova [5], indicating that after bilateral vagotomy, neurons of the intramural ganglia of the right auricle exhibit degenerating and intact pericellular networks.

The purpose of the present investigation was to study this problem in experiments permitting analysis of the morphological substrate of subordination which relates the central nervous system and peripheral reflex mechanisms.

METHOD

We conducted three series of experiments on cats (male and female): 1) Unilateral and bilateral section of pelvic nerves with subsequent examination of ganglia of pelvic organs – uterus (cervical ganglion prostate gland, urethra, urinary bladder, rectum; 2) Total removal of the spinal cord according to our own method [4] and examination of ganglia of the pelvis and peritoneal cavity; 3) Bilateral vagotomy and examination of the intramural ganglia of the heart. Animals were sacrificed 2,3, 4, and 5 days after operation. Material was prepared by silver methods: Campos, Bielschowsky – Gros (Lavrient'ev modification), and Cajal.

RESULTS

Massive degeneration of preganglionic nerve fibers and of the pericellular networks formed by them was observed 3-4 days following nerve section or removal of the spinal cord. As a result of degeneration of synaptic ringlets, boutons become homogenous forms and decompose into intensively impregnating globules. The pericellular terminal filaments which are adjacent to the cell body, or dendrites, and which form the intercellular plexus but not special terminal structures, at first acquire an intensive, black, varicose character, and degenerate into separate fragments and globules.

Intact synapses occur in ganglia along with degenerating pericellular structures. As was shown in chronic experiments involving removal of the spinal cord, synapses remain preserved indefinitely.

Thus, these experiments have confirmed earlier observations concerning the presence of synaptic connections between peripheral sensory cells (Dogiel type II) and effector neurons. These synaptic connections are accomplished by delicate axon terminal filaments entwining the soma of the nerve cell.

The terminal filaments which form the pericellular network may also cross over to other neurons or terminate in the intercellular plexus of the ganglia, where they make intimate contact with ramifications of dendrites of effector neurons and sometimes exhibit localized coils or varicose swelling [3, 4].

The correlation between degenerating and intact pericellular networks, examination of which was initiated in the present investigation, deserves separate consideration.

We were not able to show major structural differences between synaptic connections of neurons of different ganglia; however, in all examined ganglia the most typical picture is the presence on one and the same nerve cell of intact and degenerating pericellular networks from specific nerve fibers. Degenerating terminal structures also occur in the intercellular ganglionic plexus, i.e., in the terminology of certain authors, it is possible to speak of degeneration of axosomatic and axodendritic synapses of ganglia, if these terms really reflect both morphology and function.

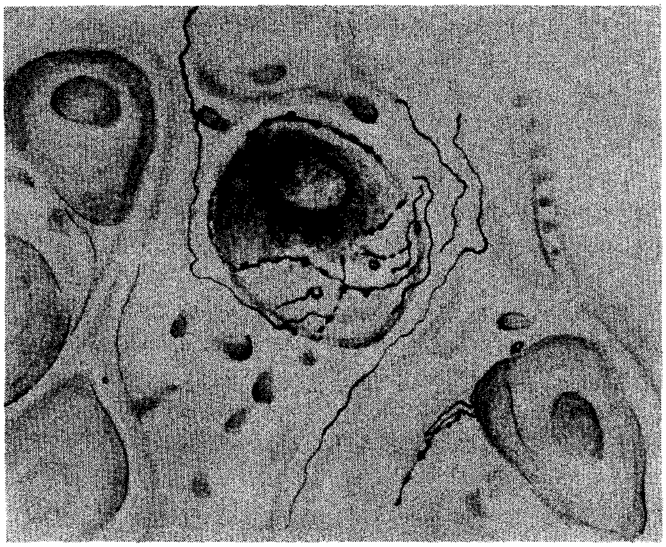

Fig. 1. Degenerating pericellular network and intact synapses in solar plexus after section of N. intestinalis.

Changes following section of N. intestinalis in the solar plexes (Fig. 1) were similar to those observed in the small urinary bladder ganglion - simultaneous representation on one and the same nerve cell of degenerating synapses and intact pericellular filaments (Fig. 2a).

Analysis of the major number of preparations revealed another, independently important fact: Neurons of peripheral ganglia do not receive equivalent innervation (at least according to the morphological picture from centrally originating preganglionic fibers and from axons of Dogiel type II cells.

In addition to individual neurons exhibiting the changes described above, there occur neurons which show only degenerating synapses, i.e., ending of centrally originating preganglionic fibers, and others with only intact pericellular networks without degenerating synapses. However, the majority of neurons in ganglia examined by us exhibit "double" synaptic connections. Along with this it was found that on individual neurons pericellular networks of various origins are not represented in the same degree. In one case there is greater development of synaptic structures of centrally originating preganglionic fibers; in the other - only one or two terminal boutons may occur, along with an intact pericellular network of terminal axon filaments which entwine the soma of the neuron and attain considerable development. The different forms of "double" synaptic connection of peripheral neurous are schematized in Fig. 3.

It is important to point out that following unilateral of peripheral sensory neurons. Consequently, interneuron endings in peripheral ganglia of the vegetative nervous system are considerably more complex than the descriptions resulting from the work of Langley.

In discussing the results of our investigations, one should compare the evidence from the literature, according to which neurons of the central nervous system exhibit endings from afferent nerve fibers of various origins; in particular, such endings occur in motoneurons of the spinal cord [10, etc.].

Some of the available material from physiological investigations can be used for a physiological interpretation of our observations. Such an interpretation involves the concept of convergence of nerve impulses, which plays an important role in analyses of the activity of neural centers and also of peripheral ganglia. Thus, Amassian and De Vito [6], Hernandez-Peon and Hagbarth [9], in electrophysiological studies, showed that an individual cell of the reticular formation of the brainstem can simultaneously receive impulses from different afferent systems or from cortical and cerebellar regions [11]. Convergence of impulses, according to a series of authors, plays an important role in the corrdination of activity and the spinal cord [12].

Directly related to the discussion are the investigations of Eccles [8], Bronk [7], etc., according to which convergence of impulses is an essential mechanism in the activity of vegetative ganglia.

Investigators believe that summation is possible durfound which are primarily dependent on one or a group of afferent systems (e.g., in one case, proprioceptive and cutaneous; in another, cutaneous and auditory; in a third, exclusively auditory; etc.).

Thus, there is a basis for our descriptions of structural relations (involving innervation of peripheral neurons by centrally originating preganglionic fibers and axons of peripheral sensory neurons) to be considered as particular cases in the structural and functional organization of the nervous system.

SUMMARY

In experiments on cats synaptic connections of the effector neurons in the peripheral ganglia of the abdominal and pelvic organs and heart were studied by the methods of experimental neuromorphology. Experimental evidence obtained confirm the data presented in the previously published works on the synaptic connections of the effector neurons with the axons of the peripheral sensory neurons. The preganglionic fibers terminate with the typical end-loops of free terminal fibers. The synaptic connection between the peripheral sensory neurons is effected at the expense of the terminal fibers distributed in the intercellular network, and entering into an intimate association with the dendrites and the cellular bodies. Double synaptic connection is found in the majority of the neurons. The morphological pictures point to an uneven innervation of the individual neurons by the preganglionic fibers and axons of the peripheral sensory neurons. Physiological investigations respective convergence of nerve impulses on individual neurons give an approach to the understanding of the mechanism governing the CNS subordinating influences on the peripheral reflexes mechanisms.

LITERATURE CITED

[1] B. I. Lavrent'ev, Morphology of the Autonomic Nervous System [in Russian] (Moscow, 1946).

[2] V. I. Pilipenko, Scientific Conference on Problems of Physiology and Pathology of Digestion [in Russian] (Abstracts of Proceedings, Kiev, 1954).

[3] V. I. Pilipenko, Byull. Éksper. Biol. i Med. 43, 4, 112 (1957).*

[4] V. I. Pilipenko, Byull. Éksper. Biol. i Med. 43, 8, 113 (1958).*

[5] I. A. Chervova, Doklady Akad. Nauk SSSR 103 No. 2 (1955).

[6] V. E. Amassian and R. V. de Vito, J. Neurophysiol. 17, 575 (1954).

[7] D. W. Bronk, J. Neurophysiol. No. 2, 380 (1939).

[8] J. C. Eccles, J. Physiol. 101, 465 (1943).

[9] R. Hernandez-Peon and K. R. Hagbarth, J. Neurophysiol. 18, 44 (1955).

[10] E. C. Hoff, Proc. Roy. Soc.(London, Ser. B, 1932) V. 3, p. 175.

[11] M. Scheibel, A. Scheibel, A. Mollica, and G. I. Moruzzi, J. Neurophysiol, 18, 309 (1955).

[12] C. S. Scherrington, Integrative Action of the Nervous System (London, 1947).

* Original Russian pagination. See C. B. translation.