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# ULTRASTRUCTURE OF AXOSOMATIC JUNCTIONS ON NEURONS OF THE RAT SENSOMOTOR CORTEX AND CELIAC GANGLIA FROM THE AGE ASPECT

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There have been several investigations devoted to the ultrastructural analysis of development of the system of interneuronal synapses at different stages of ontogeny [4, 5, 11]. In some of them, besides qualitative data, quantitative information also is given on many parameters, but these are predominantly global in nature, covering all types of junctions and not allowing for the different layers of the cerebral cortex [2]. It seemed more rational to the authors to undertake a separate study of each system of interneuronal synapses (axodendritic, axosomatic, and so on) taking into account their topographic, structural, and functional differences. The quantitative ultrastructural characteristics of interneuronal synapses of the celiac ganglia have not previously been studied from the age aspect.

The object of this investigation was to study the qualitative and quantitative ultrastructural parameters of axosomatic junctions on pyramidal neurons in the cerebral cortex and on neurons of the celiac ganglia in noninbred albino rats aged 6 months (young) and 30 months (old).

## EXPERIMENTAL METHOD

Pieces of tissue from the sensomotor cortex and ganglia of the celiac plexus from 30 rats were fixed in osmium tetroxide and embedded in Araldite. Sections were cut on UMTP-I and LKB-III microtomes and photographed on UÉMV-100B and JEM-7A electron microscopes. Axosomatic junctions were determined per unit length (10 μ) of perimeter of a pyramidal neuron in cortical layer V and on the perimeter of a ganglionic neuron. All data were obtained from 130 junctions on 90 neurons of the celiac ganglia and from 1450 junctions on 162 cortical neurons.

## EXPERIMENTAL RESULTS

Previous investigations have shown that axosomatic junctions are not numerous on pyramidal neurons [2, 12] and are rare on neurons of sympathetic ganglia [3, 8, 13, 14]. Our observations showed that there are 3.70 ± 0.22 axosomatic junctions with a junction length of 0.85 ± 0.05 μ and with an area of axon of 0.53 ± 0.06 $\mu^2$ per 10μ perimeter of a pyramidal neuron in young rats. The corresponding figures for old rats were 3.50 ± 0.23 and 0.94 ± 0.09 μ and 0.58 ± 0.08 $\mu^2$. In the celiac ganglia of young rats there were 1.5 ± 0.44 axosomatic junctions per neuron and 2.35 ± 0.47 in old rats. The axon diameter was 0.58 ± 0.035 in the young rats and 0.77 ± 0.033 μ in the old.

Axons forming synapses were found mainly in transverse section (Figs. 2 and 4). These transverse profiles could belong to "en passant" terminals and to terminal axon expansions.

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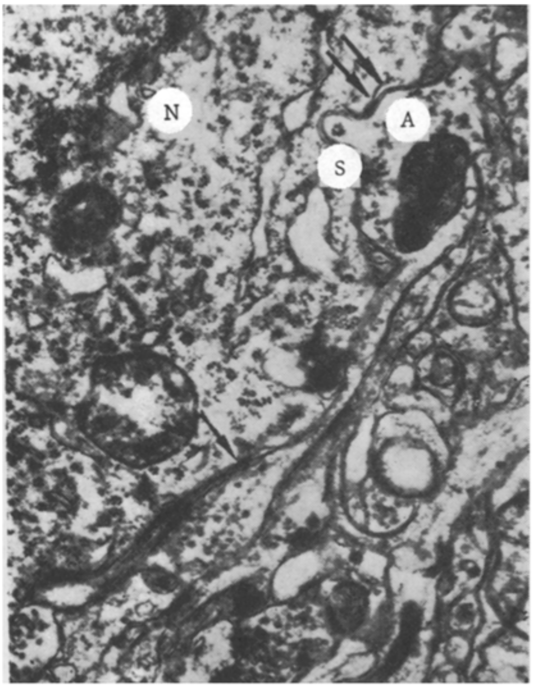


Fig. 1

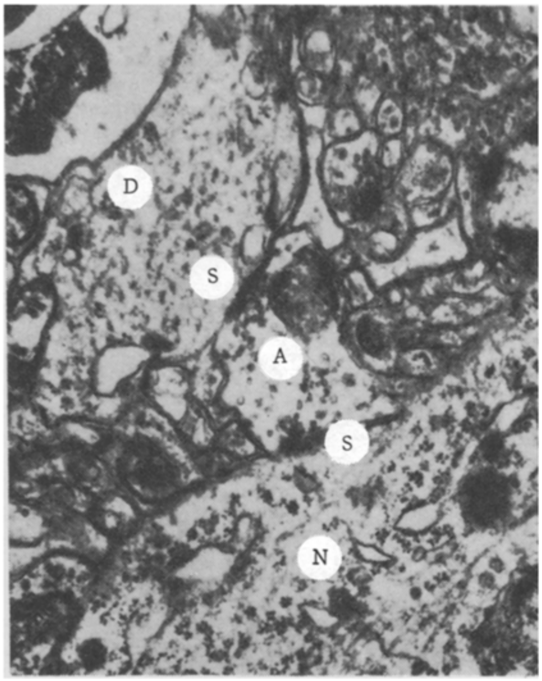


Fig. 2.

Fig. 1. Terminal portion of axon (A) with preterminal (one arrow) and terminal (two arrows) expansions. Terminal expansion forms partially invaginated junction with an active zone (S) on the perikaryon of a pyramidal neuron (N). Rat aged 30 months, 30,000 ×.

Fig. 2. Axon terminal (A) forms synaptic junctions (S) simultaneously with dendrite (D) and perikaryon of pyramidal neuron (N). Rat aged 30 months, 35,000 ×.

The discovery of a terminal portion of an axon in longitudinal section can be reliably taken to indicate a junction of end type (Figs. 1 and 3). Junctions with different three-dimensional structural relations between pre- and postsynaptic portions have been described in many parts of the nervous system [4, 6]. The diversity of the junctions was mainly due to the presence of forms ranging from superficial to deep. The axon terminal on pyramidal neurons most frequently forms a superficial junction (Fig. 2). Junctions invaginated partially and deeply into the perikaryon were rarely found (Fig. 1). Axosomatic junctions with different degrees of invagination into the perikaryon are found most frequently on cortical neurons of more highly organized animals [10]. Up to 50% of the axon membrane takes part in the formation of the junction. In the celiac ganglia four types of junctions could be distinguished: superficial, and partially, deeply, and completely invaginated. In young rats 42.0% of junctions were superficial, 46.3% partially invaginated, 10.3% deeply, and 1.4% completely invaginated. In old rats the proportions were 40.9, 27.9, 27.9 and 3.3%, respectively.

The variants of axosomatic junctions described above differed in the degree of invagination of the axon terminal into the perikaryon and, consequently, in the area of contact also. Because of this, they evidently represented interneuronal connections with different "informativeness" [4]. It can be tentatively suggested that the "informativeness" of synapses increases in order from superficial to completely invaginated. The results now obtained are evidence that the "informativeness" of axosomatic junctions in the celiac ganglia is increased in old age, for besides an increase in the relative proportion of deeply and completely invaginated junctions, the diameter of the axon terminals in these synapses also was increased. Axosomatic junctions were found around the whole perimeter of the pyramidal neurons. Axosomatic junctions at the base of the dendrites, a characteristic feature in general for sympathetic ganglia [3], were found on neurons of the celiac ganglia.

The system of axosomatic synapses is characterized by complex junctions consisting of many different components, some of which have been described in the CNS and in sympathetic ganglia [3, 4, 7]. Complex junctions formed by contiguous axon terminals, each of which is

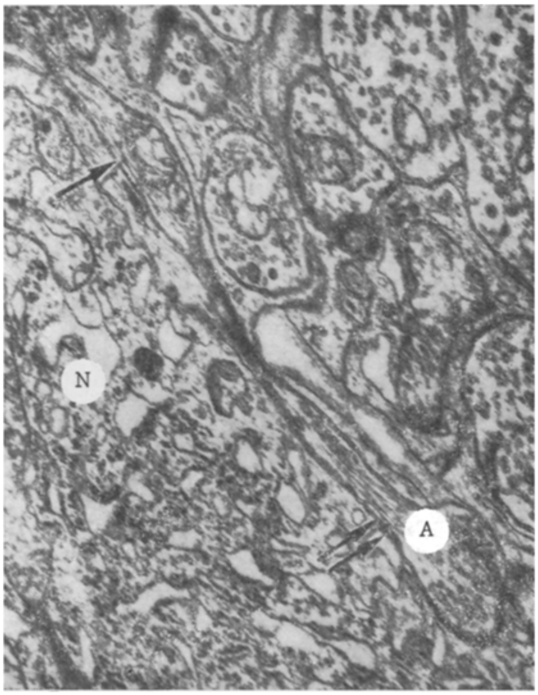



Fig. 3

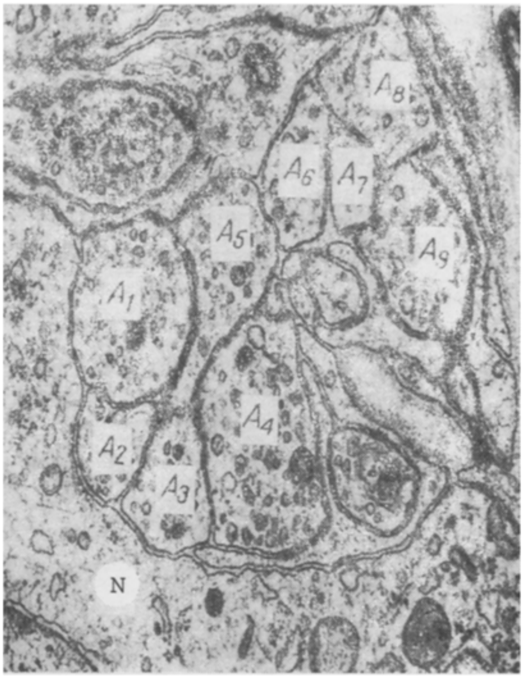



Fig. 4

Fig. 3. Terminal portion of axon (A) with preterminal (one arrow) and terminal (two arrows) expansions. Terminal expansion forms partially invaginated contact on perikaryon of celiac ganglionic neuron (N). Rat aged 30 months, 28,000 ×.

Fig. 4. Group of axon terminals forming junctions with each other ($A_1$-$A_9$, three of which ($A_1$, $A_2$, $A_3$) form junctions with perikaryon of celiac ganglionic neuron (N). Rat aged 30 months, 37,000 ×.

in contact with the perikaryon, were found on the pyramidal and sympathetic neurons of both young and old rats. Axon bundles formed by several contiguous axon terminals, some of which were in contact with the perikaryon, also were found (Fig. 4). Sometimes small areas of perikaryon (5-10 μ) with which several (3-5) axon terminals formed junctions, were found on neurons of the celiac ganglia. These complex junctions were evidently formed as a result of convergence of axon terminals on functionally highly active receptor sites of the perikaryon. Mixed junctions formed by an axon simultaneously with a dendritic spine and with the perikaryon or with a dendrite and perikaryon of a neuron also were found (Fig. 2). These were more characteristic of the sensomotor cortex and were found equally often in young and old rats. Junctions of this sort are found also in other parts of the cerebral cortex [10].

In young rats 32.8% of junctions on pyramidal neurons had active zones, compared with 41.1% in old rats. Depending on the structural specialization of the membranes, synapses on pyramidal neurons contained representatives of all types characteristic of the brain [12]. Synapses with one active zone were found most frequently. The extent of the active zone in young and old rats amounted to 23.5 and 22.3%, respectively, of the total length of the junction. Pale round vesicles, mitochondria, and multivesicular bodies were found in the axon terminal. Some vesicles always belonged to the active zone. Axon terminals in young rats contained 29.21 ± 2.27, and in old rats 32.94 ± 5.45 vesicles. In the celiac ganglia of young rats the active zones had about 30% of the junctions, compared with about 17% in old rats. In young rats all the axons contained agranular vesicles. Besides agranular vesicles, 32% of terminals contained granular vesicles. About half of the terminals contained mitochondria and multivesicular bodies as well as vesicles. In old rats, agranular vesicles were found in all terminals, granular vesicles were found in 47% of terminals, and 70% contained mitochondria and multivesicular bodies.

A characteristic feature of the pyramidal neurons and neurons of the celiac ganglia was that only some axosomatic junctions had active zones. In each part of the nervous system the fraction of active junctions evidently corresponds to a particular quantitative level, which characterizes the functional state of the corresponding systems of interneuronal synapses (axosomatic, axodendritic, and so on). The fraction of active junctions changes during ontogeny, with a change in the functional state of the nervous system. The structural and functional plasticity of the system of synaptic junctions is manifested in animals during learning and during pharmacological stimulation of the nervous system [9], and it is expressed as a change in the fraction of functionally active synapses rather than a change in the total number of junctions [1, 2].

The results of the present investigations show that the system of axosomatic connections of pyramidal neurons and of neurons of the celiac ganglia in old age possesses ultrastructural features of high structural and functional plasticity. In the sensomotor cortex the mean dimensions of the axosomatic junction remains relatively stable during the period of ontogeny covered by this investigation, whereas the fraction of active junctions increases, evidence of some increase in the activity of this system of synapses in old age. In the celiac ganglia in old age, besides a decrease in the fraction of active junctions, an increase is observed in the diameter of the contacting axons and in the number of deeply and completely invaginated junctions. The changes described in the system of axosomatic synapses of pyramidal neurons and neurons of the celiac ganglia develop evidently in the course of wastage of neurons and their synapses during aging and they are of compensatory and adaptive significance.

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