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Plasticity and Stability of Synapse Architectonics of the Cerebral Cortex

N. N. Bogolepov

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Changes in the interneuronal contacts and recombinant changes in the synapse architectonics play an important role in its plasticity. Along with the reorganization of the synapse architectonics, these changes are attended by an increase or decrease in the number of interneuronal contacts.

Key Words: *synapse; plasticity; recombinant changes*

The plasticity of synapse architectonics (SA) is a key aspect of the organization of interneuronal connections. D. S. Sarkisov [8] considers that there are two ways in which structural and functional changes occur in organs and tissues. One is the accumulation or depletion of certain elements in a system, leading to new qualitative differences, and the other is the appearance of a new quality in a system that is attained not by an increase or decrease in the number of its components, but solely by their reorganization and recombinant transformations.

We have been studying the ultrastructure of synapses, their development, pathology, organization, and relationships with the cytoarchitectonics and structure of neurons in the cerebral cortex for many years in our laboratory and have come to the conclusion, based on our findings and published data, that SA of the cerebral cortex is not a stable fixed structure, but a dynamic system in which changes occur constantly: some interneuronal contacts disappear, while new ones are being formed all the time [2-4].

The plasticity of interneuronal connections in the cerebral cortex has been demonstrated in many studies [10,12].

Research Institute of the Brain, Russian Academy of Medical Sciences, Moscow (Presented by D. S. Sarkisov, Member of the Russian Academy of Medical Sciences)

Changes of SA are associated with an increase or decrease of the number of interneuronal contacts or predominantly with reorganization of the interneuronal connections with no change in their total quantity.

The mechanisms of plasticity of individual interneuronal contacts include alterations of the shape of membranes coming in contact with each other (transition of positive and negative synapses to flat, etc.), changes of the area of the active zone of a synapse, of the number of active zones between a presynaptic process and a postsynaptic process, and the formation of perforated synapses. The most significant of these features are changes in the size and number of active zones between the axon and dendrite making contact with one another.

Synapses of different localization usually have active zones different in size. For example, small branches of axons and dendrites have contacts which are smaller than the synapses on the large branches of dendrites; axodendritic synapses have, as a rule, larger active zones than axosomatic synapses. Synapses formed by axons "alongside" (or tangentially), usually have active zones of short length in transverse sections, whereas the terminal contacts are formed by a widening of the axon and have large active zones. We should emphasize that, within the framework of these general regularities, the number of synapses with "po-

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int" active zones increases as the functional activity of the active zones is enhanced. Such a phenomenon was observed, for example, in the visual system during light stimulation. An opposite picture was observed during light deprivation.

Dynamic changes of the cerebrocortical SA during functional loading were demonstrated both in our experiments and in experiments performed by many other scientists. During long physiologically equivalent loading or systematic training the number of synapses (primarily axodendritic) somewhat increases. This was demonstrated in experiments with photostimulation in the visual cortex and with motor training in the sensorimotor cortex. However, the number of synapses in the brain cortex can increase only by 2 to 10%, that is, comparatively little.

It should be stressed that an increase or decrease in the number of synapses during functional loading or functional deprivation has usually been studied during very intensive and prolonged exposures. During functional adaptation under conditions of everyday behavioral reactions the reorganization of SA takes place with no changes to the total number of contacts and structural organization of the afferent-efferent relationships. An important factor is that the dynamic changes in the interneuronal connections take place within a stable carcass of cytoarchitectonics and neuronal organization. Some interneuronal connections may change under functional influences, thus performing adaptive functions.

Recombinant changes of SA do not rule out an increase or decrease in the number of synapses as mechanisms of adaptation during intensive functional loading or overloading or as a compensation for dysfunctions during pathology.

Kupriyanov [6] theorizes that where man is concerned, an increase of the information flow called for an increase of the intracentral connections and the appearance of new associative formations. The number of interneuronal connections changes markedly during compensatory processes [1].

On the other hand, a large portion of synapses in the central nervous system remain stable, providing one of the structural foundations of homeostasis.

SA changes also develop during the formation of pathological systems [5]. An example is the formation of new misconnections in the brain cortex during chronic morphine intoxication, which we demonstrated experimentally. We hypothesized that this pathological neoformation of synapses leads to changes of SA of the brain cortex in general, interferes with the associative function, and serves as the structural basis for the formation of a physical dependence on the narcotic [7]. The formation of new synapses in such a case is interrelated with the growth of fine ramifications of axons and dendrites, that is, not only is the composition of synapses altered, but the neuropil structure as well. Our studies of the synaptic neoformations showed that the number of synapses with "point" and small active zones was most notably increased. A stable reliable increase in the number of interneuronal connections is the morphological basis of the full-blown stage of morphine narcomania, coinciding with the development of physical dependence. The time course of SA changes to a certain degree corresponds to the clinical stages of narcomania.

S. A. Sarkisov [9] demonstrated the plasticity of the structure of cerebrocortical neurons, showing how reversible changes occur in the spines and small dendrite branches during different experimental interventions. Changes in the spines are related to changes of the synapses situated on them. Our findings indicate that, on the one hand, the spines are the most vulnerable structures of dendrites and, on the other, in some situations they are extremely stable in comparison with the ultrastructure of dendrites. Further studies of the ultrastructure of the spines and their role in the SA of the brain cortex will disclose more and more about the role they play in the structural and functional organization of the cortex, as our findings and recent published reports [11] attest.

The focus on spines and the changes thereof is not accidental, since numerous synapses are localized on them and in some cases the synapses on the spines form a kind of synaptic sleeve around the dendrite. It is the spines that most readily change their size, shape, ratio between neck and head, configuration of the synaptic contact, etc. In other words, the spines and synapses on them represent one of the most plastic components of SA.

Hence, we may conclude that the plasticity of SA is fashioned from the plasticity of individual interneuronal contacts, recombinant changes of interneuronal connections, and, finally, reorganization of SA with an increase or decrease in the number of contacts. The bulk of the synapses formed under the influence of genetic factors and in the course of individual development determine the stability of the structural and functional organization of the brain cortex.

REFERENCES

1. O. S. Adrianov and N. N. Bogolepov, in: *Functional and Structural Basis of Systemic Activity and Mechanisms of Brain Plasticity* [in Russian], Vol. 4, Moscow (1975), pp. 9-18.
2. N. N. Bogolepov, *Ultrastructure of Synapses in Health and Disease* [in Russian], Moscow (1975).
3. N. N. Bogolepov, *Morfologiya*, **102**, № 2, 49-63 (1992).
4. N. N. Bogolepov and A. S. Pushkin, *Vestn. Akad. Med. Nauk SSSR*, № 12, 12-29 (1978).
5. G. N. Kryzhanovskii, *Determinant Structures in Nervous System Pathology* [in Russian], Moscow (1980).

6. V. V. Kupriyanov, *Methodological Problems of Human Anatomy* [in Russian], Moscow (1985).
7. G. V. Morozov and N. N. Bogolepov, *Morphinism* [in Russian], Moscow (1984).
8. D. S. Sarkisov, in: *Recombinant Transformations as a Mechanism of Qualitative Changes in Living Systems* [in Russian], Moscow (1994), pp. 2-36.
9. S. A. Sarkisov, *Peculiarities in the Structure of Neuronal Contacts in the Brain Cortex* [in Russian], Moscow (1948).
10. E. Fifkova, in: *Neuroplasticity, Learning, and Memory*, New York (1987), pp. 61-86.
11. K. M. Harris, F. E. Jensen, and B. H. Tsao, in: *The Hippocampus*, V. Chan-Palay *et al.* (Eds.), New York (1992), pp. 33-52.
12. T. L. Petit, in: *Neural Plasticity: A Lifespan Approach*, New York (1988), pp. 201-234.

The Mechanism of Pulmonary Hypertension in Rats with High-Altitude Hypoxia

B. I. Mazhbich, L. M. Nepomnyashchikh, and E. L. Lushnikova

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Morphofunctional examinations of the lungs of rats exposed to high-altitude conditions for 3 to 300 days revealed that systolic pulmonary hypertension observed during the entire period of study is caused by a total increase of the elastic resistance of pulmonary arteries. Adequate bloodflow in such a case is provided by intensive work of the right-ventricular myocardium against this resistance.

Key Words: *high–altitude; pulmonary vessels; pulmonary hypertension; vascular resistance*

High-altitude hypoxia is regularly associated with rise of pressure in the pulmonary artery [4]. Usually hypertension in the pulmonary circulation is diagnosed from a rise of the mean pressure, and the actual process of pressure change is modeled on the basis of Poiseuille's model of the circulation, according to which a pressure rise in this vascular bed with the bloodflow decreased or intact means an increase of the pulmonary peripheral resistance (PPR). However, structural changes in the pulmonary network of vessels are diverse and cannot be interpreted unequivocally solely as an increase of PPR.

Therefore, the purpose of our study was to analyze the pulmonary hemodynamics under high-altitude conditions on the basis of natural pressure values in the pulmonary artery together with other hemodynamic parameters and data on the structural changes developing in the lungs during the exposure of animals to a mountain environment.

Institute of Physiology, Siberian Division of the Russian Academy of Medical Sciences; Institute of Regional Pathology and Pathomorphology, Siberian Division of the Russian Academy of Medical Sciences, Novosibirsk (Presented by V. A. Trufakin, Member of the Russian Academy of Medical Sciences)

MATERIALS AND METHODS

Experiments were carried out in summer with male Wistar rats brought to an altitude of 3200 m above sea level beforehand and kept at room temperature on the standard diet. Animals kept under the same conditions on the plain were controls.

The pressure was measured and pulmonary bloodflow, blood filling, and air content in the lungs per unit volume of the organ were assessed by catheterization of a lung artery through the jugular vein and transbronchial electroplethysmography. The parameters were recorded using a Siemens-Elema Mingograf-34 ink-jet recorder. The methods of investigation were described in detail previously [3]. The animals were exposed to the mountain altitude for 3, 10, 20, 30, 60, 150, and 300 days. After the experiments the lungs

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