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MICROGRAVITATIONAL NEUROGONIOMETRY AS A NOVEL MEASUREMENT TOOL FOR THE COMPLEX MORPHOFUNCTIONAL, MORPHOBIOCHEMICAL AND MORPHOPHYSIOLOGICAL STUDIES OF THE NEURON BIOPHYSICAL STATE IN SPACE CONDITIONS FOR EXPERIMENTS ON BIOSATELLITES

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Abstract. The effect of weightlessness / microgravity on the characteristics of the charge transfer across the neuron membrane is well known in space biology and medicine. In the absence of any gradients determining the growth directions of the neurites the neuron has a spherical shape characterized by the minimal surface. From the standpoint of functional morphology, it seems reasonable to design a system for a simultaneous monitoring of the electrobiophysical / electrophysiological and neuromorphological state of the brain neuronal structure, nervous tissue culture or the living slices directly in the microgravity / weightlessness conditions during the space flight. We have earlier developed a five-axis robotic positioning system for measurements on the living slices and tissue cultures, which demonstrated the dependence of the certain structure morphogenesis on its orientation in the gravitational field and external fields, as well as its correlation with the directed electrophysiological activity. The above system can be easily adapted to the astrophysical microgravity conditions.

Keywords: microgravitation, minimal surfaces, orbital station, biosatellites, spherical surfaces

Background

The effect of weightlessness / microgravity on the characteristics of the charge transfer across the neuron membrane is well known in space biology and medicine (Wallace, 1995). In some cases this leads to the disorders in the neuron morphogenesis and the neurites' orientation due to the lack of the native forces which normally affect the neuron morphogenesis, resulting in disorientation in the gravitational field and significant changes in the normal diffusion and biorheological parameters (Sanderson, 1990; Crestini, 2004; Horn, 2006; Ranjan, 2014). In the absence of any gradients (Baier, 1992; Tessier-Lavigne, 1992; Baier, 1995; Bravo, 1997; Goodhill, 1998; Rosentreter, 1998; Legg, 2003; Davis, 2003; Goodhill, 2004; Flanagan, 2006; Suter, 2007; Thivierge, 2007; Caviness, 2009; Sundararaghavan, 2009; Millet, 2010; Martínez-Morales, 2011; Snyder, 2011; Keenan, 2012; Charvet, 2014; Kim, 2015) determining the growth directions and morphogenesis of the neurites the neuron has a spherical (Sala, 1990) shape characterized by the minimal surface (Sabitov, 1967) in homogeneous spaces (Van, 1989). Thus, in this case there is a topological transition since in the natural conditions of the orientated growth the tubular shape is the most probable one from the physical principles (Borisovich, 1997; Klyachin, 1997).

The authors have found and examined a series of slides in the collection of the former Brain Research Institute (Brain neuronal structure laboratory). According to the private communications which refer to the morphometric papers (Belichenko, 1988, 1989, 1991) describing the results obtained on the biomaterials from the biosatellite "Kosmos-1667" ("Bion-7"), the prolonged flight causes a partial involution of the neurites and spines leading to the pseudo-spherical neuron shape (see also clippings from contemporary works in the Figure 1).

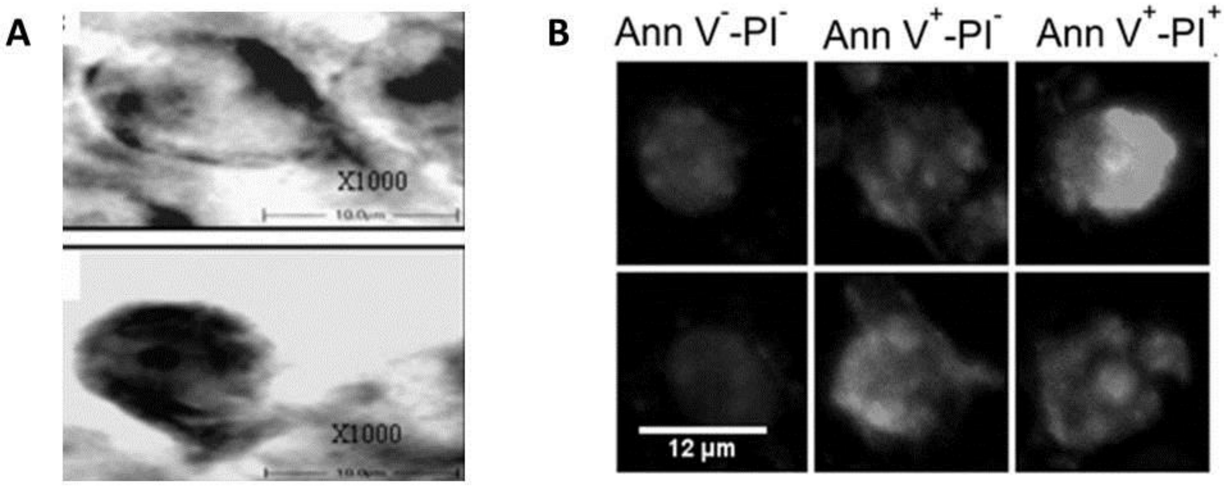

Figure 1. Some typical pseudo-spherical neuron shapes from microgravitational conditions: A – adapted from (Ranjan, 2014); B – adapted from (Pani, 2013). Copy from the convolute archive of E.D. Adamovic.

General Principles

From the standpoint of functional morphology and a morphophysiological trend in the multivariate data analysis in situ, it seems reasonable to design a system for a simultaneous monitoring of the electrobiophysical / electrophysiological and neuromorphological state of the brain neuronal structure, nervous tissue culture or the living slices directly in the microgravity / weightlessness conditions during the space flight. We have earlier developed a five-axis robotic positioning system for measurements on the living slices and tissue cultures (Notchenko, 2013; Gradov, 2014; Gradov, 2014a; Oganessian, 2014), which demonstrated the dependence of the certain structure morphogenesis on its orientation in the external fields, as well as its correlation with the directed electrophysiological activity. The above system can be easily adapted to the weightlessness conditions.

We have already performed a calculation and design of the culture box – lab-on-a-chip – and a vital electrophysiological system for stereotactic positioning, which allow to study the coupled (morphofunctional / morphophysiological) changes in the electrophysiological activity modes and in the morphological / morphometric parameters of the neuronal structures (both in vivo or in situ, as well as in vitro on the living slices or tissue cultures) in the space flight conditions, as well as in natural conditions and under centrifugation.

Our preliminary data about neurogoniometry has been reported at the conference (see Figure 2) and the detailed publication of the technical documentation will also appear soon.

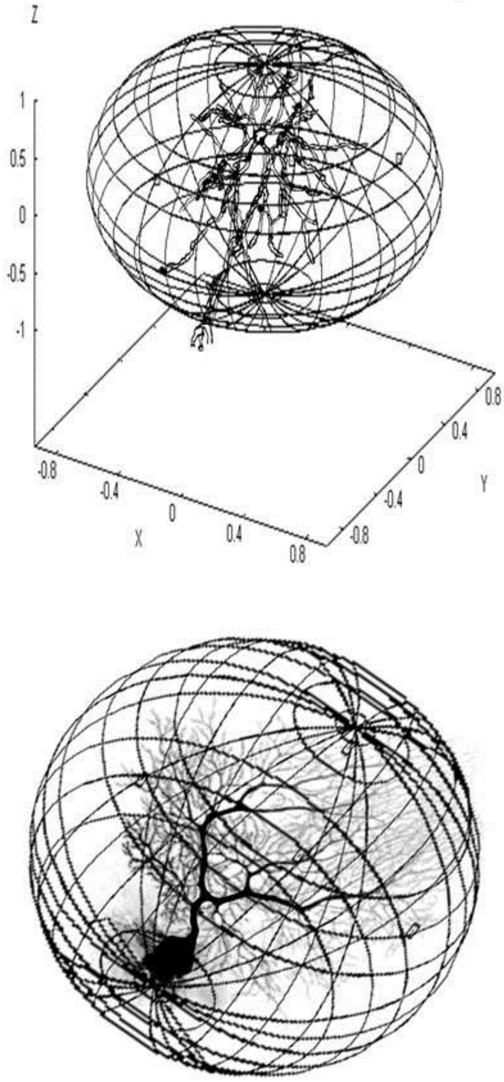

Figure 2. A scheme of neurogoniometry in spherical coordinates (from our conference paper and poster in the "International Symposium on Functional Neuroimaging – 2012" (Notchenko and Gradov, 2012)).

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