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Microfluidics Applications In Fundamental And Medical Studies In Neuroscience

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Summary. Today many fundamental questions in Neuroscience can be addressed with Microfluidics methods which provide unique approaches for cell patterning and control neural branch outgrowth. Such methods can be used to gwoe separate subpopulations of dissociated neurons connected with uni-directional connectivity. Combined with microelectrode arrays such approach can be used to simulate and study neurogenesis, learning and information coding in neural networks.

Key words. Neuronal cultures, microelectrode arrays, PDMS microchannels, synaptic plasticity.

INTRODUCTION

Today many fundamental questions in Neuroscience such as neuron synaptic coupling in various conditions, synaptic connectivity in the network, morphological structure and cell layers formation and many others require a development of new methods for cell manipulation and observation. Microfluidic chips containing chambers for cell plating can be easily fabricated and used for long-term imaging. and electrophysiological signal registration on MEA (microelectrode arrays).

RESULTS

In this study we designed a microfluidic device combined with microelectrode array which allows to grow two separated neuronal cultured networks with directed synaptic pathways inbetween into pre- and postsynaptic subpopulations of neurons. We investigated signal propagation through axonal pathways using different shapes of the microchannels in order to find optimal method to control axon outgrowth. After 10 DIV the axons coupled two cultures through 8 microchannels. We found that spontaneous bursts in presynaptic chamber evoked burst in postsynaptic chamber. Also we tested the direction of synaptic pathways in the microchannels by electrical stimuli applied to random electrodes in the pre- and postsynatic chamber. Then we designed PDMS chips with two-chambers and three-chambers to investigate different methods of synaptic connectivity modification between neuronal subpopulations. We used high frequency paired pulse stimulation to evoke potentiation of the synapses between neurons in separated chambers. Such direct approach can be used for study of synaptic plasticity on the network level. Also we used microfluidic device to study progenitor cells differentiation in presence of growth factors expressed by other neurons in order to find optimal conditions for neural tissue regeneration. One separate chamber was used to grow the cells dissociated from embryonic mice (E18) and other chamber for neurospheres (hippocampal progenitor cells E14). We found that progenitor cells differentiated in 7 days and formed synaptic connectivity with mature culture (E18) grown in opposite chamber. Such methods can be used to investigate stem cells and progenitor cell differentiation and functional integration in the brain. The results can be used in the study of neuroprostethics, neuroreabilitation.

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