Cultured neural networks: spontaneous activity, bursts and learning capabilities

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Neuro-electronic interfacing operates at the crossing of neuroscience, tissue and cellular engineering, signal processing and micro(nano)fabrication. The aim is to engineer large-scale connections between the electronic and the neuronal world. For rehabilitation of sensory or neuromuscular functional deficits, for future brain-computer interfaces, to provide new tools to the brain researcher or to bring about - and understand - the process of learning in live, cultured neuronal networks.

For the purpose of efficient neuro-electronic interfacing, the development of 'cultured probe' devices is an attractive and challenging endeavor. A 'cultured probe' is a hybrid type of neural information transducer or prosthesis, for stimulation and/or recording of neural activity in the brain or the spinal cord (ventral motor region or dorsal sensory region). It consists of a MEA (Multi Electrode Array) on a planar substrate, each electrode being covered and surrounded by a local, circularly confined network ('island') of cultured neurons, obtained by chemical patterning of the substrate. The purpose of the local networks of cultured cells is that they act as intermediates for collateral sprouts from the in vivo system , thus allowing for a highly effective and selective neuron electrode interface. As the local neural network can also become spontaneously active and therefore has the principal capability of information processing, one may envisage future applications of these intermediary networks as 'front-end' signal processors.

As cultured probes contain live networks of cultured neurons, the spontaneous and induced activity of these networks have to be evaluated on their wanted and unwanted aspects during operation of the cultured probe as a prosthetic device. Among these are the classification of recorded wave shapes of spontaneously active neurons, characterization of spontaneous activity in rhythmic single neuron activity and periodic population burst activity, the neuronal activity in unconnected and connected 'island' networks, synchronized activity between connected 'islands' and the (un)ability to train networks to learn networks specific stimulus-response behavior (artificial learning). Can they learn ?

A general problem in the development of (local) cultured neural networks is that eventually the flat networks tend to aggregate into (3D) clusters or that islands tend to become connected by fasciculated neural interconnections. (Chemical) optimization of the network-to-substrate adhesive properties is therefore also an important research goal.