9. ELECTROPHYSIOLOGY – INVASIVE AND NON-INVASIVE BIONIC INTERFACES

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The Electrophysiology Laboratory was established by the University as a research and education facility, located in the Jedlik building. The Laboratory heavily collaborates with the Institute of Cognitive Neuroscience and Psychology, Institute of Technical Physics and Materials Science (RCNS HAS), Institute of Experimental Medicine (HAS) and the National Institute of Neurosciences. The Laboratory integrates several disciplines including electrophysiology, materials science, chip- and micro electromechanical systems (MEMS) research, computational research, neurology research and optical imaging research in order to investigate the physiological and pathological functions of the central nervous system.

Two rooms are assigned to the Laboratory one for conducting experiments and the other for data processing. In the experimental room there are two computers capable of acquiring and analyzing bioelectrical signals, a stereo-microscope and stereotaxic device essential for animal experiments and several supplementary tools (oscilloscope, amplifiers, sterilization tools, electrical and mechanical stimulators and animal keeping chamber). In the data processing room there are three computers with software necessary to analyze the large volume of data generated in the experimental room.

The Laboratory is involved in bionic probe research by designing and validation of various probe structures realized by the partners. These probes are usually brain implantable devices, which can detect electrical activity of cortical and sub-cortical structures in animals. We are also providing histology studies to verify the biocompatibility of the devices developed. Besides Hungarian partners, the Laboratory is also involved in probe design and testing at IMEC (Belgium) and IMTEK (Germany) in the scope of an EU FP7 project. We also take leading role in the research and development of active probes used in the study of of multi-scale interactions in the thalamo-cortical system in animal models.

The Laboratory is also involved in the investigation of the cortical generators of event related potentials, spontaneous and epileptic activity in animal models and in humans. A number of collaborative research projects are running on the field of in vivo and in vitro electrophysiology and optical imaging in epileptic and tumor patients and in animal models. In particular, one of our current main research interests is the functional characterization of the thalamo-cortical neural networks responsible for the sensory information processing.

Recently, in collaboration with our partners we investigated the cortical sources of slow sleep oscillations in humans. We described several unique characteristics of neocortical neural networks during depolarized and hyperpolarized phases of the sleep slow oscillation. Our results showed that in the generation of slow oscillation the superficial cortical layers played a leading role, in contrast to animal models, where the deep layers were more involved. In addition, we have shown that human cortical neurons fire substantially less than neural cells of animals and this firing pattern may have an important role in memory consolidation during sleep.

We have also characterized the function of cortical neural networks in animal models during the sleep-wake cycle concentrating on the cortical acoustic information processing. We have found that acoustic stimuli can induce either depolarized or hyperpolarized state transition of cortical slow oscillation during deep sleep, which may be instrumental in triggering both arousal and sleep preservation mechanisms.

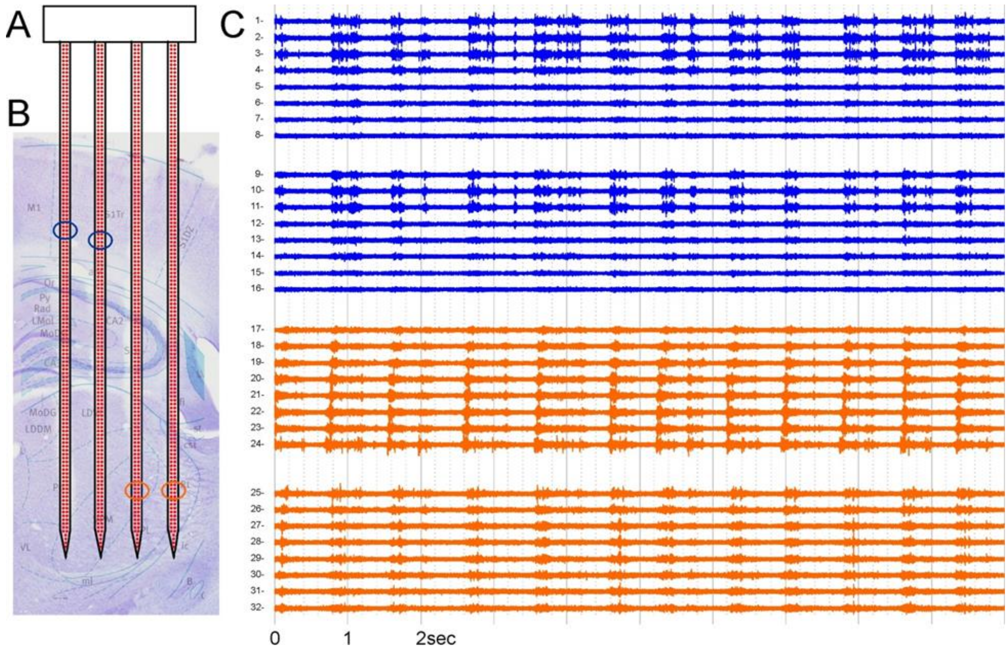

Fig. 1 **A:** *Schematic picture of the electronic depth control probe developed in an EU FP6 collaboration. The innovative feature of the probe is the electronically addressable recording site selection that allows the experimenter to change registration areas without physically moving the probe in the brain. The lack of movement is beneficial in the preservation of neural activity.* **B:** *The anatomy of the thalamo-cortical system with schematic drawing and actual histology.* **C:** *Action potential activity during anesthesia with slow waves. Cortical action potential activity is marked in blue, thalamic action potential activity is marked in red.*

Since 2014 the Laboratory is involved in the Hungarian Brain Research Program, with the Institute of Cognitive Neuroscience and Psychology, Institute of Technical Physics and Materials Science (RCNS HAS), Institute of Experimental Medicine (HAS) and the National Institute of Neurosciences.

In this program the Laboratory is involved in the designing and testing of foil based electrodes fitting on the brain surface, useable in Elecrtocorticography studies, and with electrodes implanted in the brain tissue the activities of the neurons near the electrodes are recordable. The fusion of the two technique gives a new insight to the connection of the signals detected on the brain surface, and the laminar recordings. These MEMS based electrodes were tested with electrochemical impedance spectroscopy in vitro and in vivo, and their biocompatibility is also promising.

The Laboratory is involved in the development of MR compatible and /or multichannel amplifiers useable in human or animal studies. Two photon imaging, and analysis methods are developed, for human and animal studies, of the evoked rhythmic population activity. The fusion of the electrophysiologycal and optical imaging in vitro and in vivo is under development in the Laboratory. The cortical and hippocampal, epileptic and physiological population activities are under investigation in human and animal model. There are brain computer interface studies for registratory, and intervening EEG, EOG, EMG and eye movement following algorhythms.

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