Synchronization phenomena on complex networks 2, from math to experiments
- Special workshop for AIMR Advanced Target Projects -

Date: Wed, Jan 8, 2020, 13:30–17:30
Venue: Tohoku Forum for Creativity, 3F, Lecture Theater,
Katahira Campus, Tohoku University.
Access: `http://www.tfc.tohoku.ac.jp/about_us/contact_and_access.html`

13:30 – 14:10

Hiroya Abe (AIMR, Tohoku University)

Amperometric electrochemical imaging device for monitoring neural activity

Techniques for visualizing (imaging) neurotransmitters such as dopamine and glutamate significantly contribute to a revelation of brain functions, drug discovery studies and an establishment of therapeutic method. We have been developed large scale integration (LSI)-based electrochemical sensors, which have, designated as Bio-LSI, with high sensitivity, high resolution (number of sensors: 400, Sensor spacing: 250 μm) and real-time imaging (up to 1 ms). In this presentation, I will talk about Bio-LSI device for monitoring a neural activity. I have successfully monitored dopamine released from neuron-like 3D-cultured cells and selectively imaged neurotransmitters in the presence of an interference.

14:20 – 15:00

Hiroaki Onoe (Department of Mechanical Engineering, Faculty of Science and Technology, Keio University)

Microfabricated hydrogel culture environment for 3D neural tissue engineering

Hydrogel-based microfabricated tissue scaffolds have been intensively studied for providing designed environments for 3D tissue culture in vitro and in vivo. In this presentation, I introduce recent progress on the microfabricated hydrogel culture microenvironments for 3D neural tissue reconstruction. (1) microfluidically synthesized hydrogel microtubes were demonstrated for constructing fiber-shaped 3D neural tissues for creating a neural connection. These microfiber-shaped 3D neural tissues can be connected to each other for propagating neural signals. (2) 3D-shape-controlled neural tissue microarray with closed agarose microchamber for drug testing. By confining neural tissues inside the chamber, the growth and shape of the 3D neural tissue can be precisely controlled, causing the difference in neurites density and position in the 3D tissues.

15:10 – 15:50

Shigeru Shinomoto (Department of Physics, Kyoto University)

Reconstructing neuronal circuitry from spiking signals

It was found in more than 100 years ago that the brain consists of distinct regions expressing different histological structures. Since then it has been revealed that the brain regions classified according to histology are working for sub-categorical functions of sensation, association, and motion. Thus it is expected that neurons are connected differently in different brain regions for transmitting and processing different kinds of information. Researchers have attempted to reveal the neuronal circuitries. Individual connections may be identified using intracellular or patch-clamp recordings where the postsynaptic current caused by presynaptic neuronal firing can be measured, but they are limited because only a few neurons can be recorded simultaneously. With the recent increase in parallel high channel count extracellular recordings, it is possible to estimate the connection strength between a large number of neurons. It has been suggested for more than 50 years that the inter-neuronal connectivity can be estimated by analyzing the correlation between neuronal signals. But it was not easy to perform the estimation, because real biological data are contaminated with large fluctuations caused by external signals or the interaction among many other neurons. We applied a generalized linear model to identify pairs of neurons with millisecond differences in spike timing to determine the pairs that were likely monosynaptically connected [1]. With the method, neuroscientists may obtain a connectivity diagram of neurons from a set of spike trains they record from animals.

[1] R. Kobayashi, S. Kurita, A. Kurth, K. Kitano, K. Mizuseki, M. Diesmann, B.J. Richmond, and S. Shinomoto, Nature Communications (2019) 10:4468.

16:00 – 16:40

Kenta Shimba (School of Engineering, The University of Tokyo)

Microelectrode array with microtunnel structures for multiscale neurophysiology study

In neuronal network, neurons are interconnected through axons. Conventionally, axon is regarded as a cable for conducting digital impulse. However, recent study reported that conducting action potential is analogue signal, but not digital one. After the report, modulation during axonal conduction attracts great interest. We have developed culture devices with microtunnel structures on a microelectrode array for recording propagating action potential along axons, and the culture device is applied to several topics. In my talk, I will introduce several topics with culture devices, including sub-cellular, inter-cellular, and inter-network level study.

16:50 – 17:30

Shoi Shi (Graduate school of Medicine, The University of Tokyo)

Identification of sleep genes by mathematical model and mouse genetics

A primary goal of sleep research is to answer the question that how sleep duration is regulated. To address this question, we developed a series of simple computational models of a cortical neuron with

multiple channels, which recapitulates the cortical electrophysiological characteristics of slow-wave sleep (SWS) and wakefulness. Comprehensive bifurcation and detailed mathematical analyses predicted that a part of Ca^{2+} channels and K^{+} channels play a role in generating the electrophysiological characteristics of SWS, leading to a hypothesis that these channels play a role in the regulation of sleep duration. To test this hypothesis experimentally, we comprehensively generated and analyzed KO mice of these predicted channels, and found genes in Ca^{2+}-dependent/independent hyperpolarization pathways play a role in regulation of sleep duration in mammal.

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