【Grant-in-Aid for Transformative Research Areas（A）】

Multicellular Neurobiocomputing: Understanding and Advancing towards Biological Supremacy

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Project Information	Project Number : 24A401　Project Period (FY) : 2024-2028 Keywords : Neuronal networks, mathematical modeling, bioengineering, neurobiology, neuromorphic hardware

Purpose and Background of the Research

●Outline of the Research

The human brain is composed of unstable biological elements called neurons. Nonetheless, it performs complex information processing with high energy efficiency and adaptability. Such properties does not appear in single cells and cannot be explained as their linear summation. It is only through the **multicellular network** formed by the precise wiring of a diverse array of neurons that the system-level function of a brain emerges for the first time.

In pursuit of a super-smart society, referred to as Society 5.0, the brain is being used as a model to improve machine learning technologies. However, current technologies fall short in fully mimicking the brain. A deeper understanding of the nervous system could lead to what might be called "**biological supremacy**," akin to quantum supremacy in quantum computing. This advancement could drive the development of next-next generation information and communication technology (ICT) (Fig. 1).

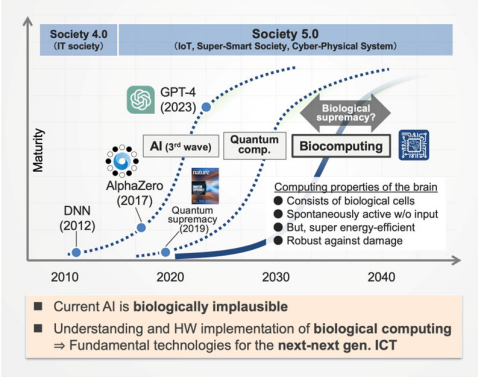

Figure 1. Expectations for biocomputing research

●Research Strategy

We set the following three domains to integrate different research fields towards understanding the fundamental basis of multicellular computing (Fig. 2):

① **Multicellular modelling**: Formulating bioplausible models of sensory-motor control

② **Multicellular hardware**: Developing ultra-low power neuromorphic systems

③ **Multicellular wetware**: Building artificial systems using living neurons

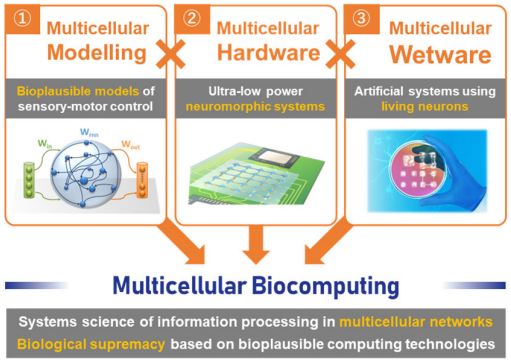

Figure 2. Strategy of the Research Area

●Overview of the Research Groups (Planned Research)

We set the following four Research Groups to advance towards Biological Supremacy in the three domains (Fig. 3).

- **A01 Information Science Group:** Extract metrics from large-scale data on multicellular neuronal dynamics (**Matsui Team**) and formulate them as mathematical models (**Katori Team**).
- **A02 Bioengineering Group:** Build biointerface technologies (**Tanii Team**) to test the models formulated for normal (**Yamamoto Team**) and pathological (**Hirano-Iwata Team**) networks in living neurons.
- **A03 Systems Neuroscience Group:** Obtain physiological data on multicellular computing and underlying synaptic functions using in vivo calcium imaging (**Masamizu Team**) and electrophysiological recording (**Kamiya Team**).
- **A04 Hardware Applications Group:** Develop hardware for implementing multi-cellular models (**Kohno Team**) and apply it for adaptive robot control (**Hirata Team**).

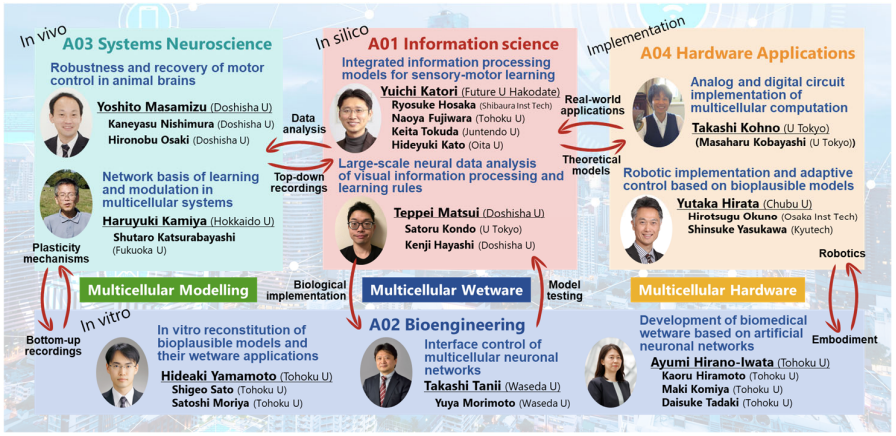

Figure 3. Members of the Planned Research and their collaborations

Expected Research Achievements

Expected achievements include a mathematical formulation of the interplay between the collective behavior of biological elements (cells) and their function as a system (neural system) and understanding its engineering advantages. We integrate core technologies stemming from multiple disciplines to realize this goal. (Fig. 4)

Fostering international and interdisciplinary collaboration, along with nurturing young talent that paves the way for the next generation, is also a critical mission of our project.

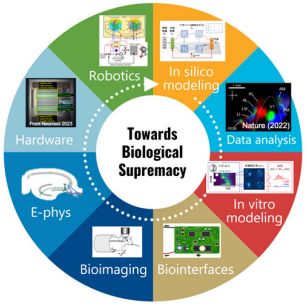

Figure 4. Core technologies

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