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Media release

The Allen Institute
The University of Electro-Communications

One of World's Most Detailed Virtual Brain Simulations is Changing How We Study the Brain

Scientists use supercomputer that can process quadrillions of calculations per second to simulate mouse cortex for "virtual experiments"

※This document is a domestic version of the original release from the Allen Institute, edited by Associate Professor Tadashi Yamazaki (Department of Computer and Network Engineering, Graduate School of Informatics and Engineering, The University of Electro-Communications), Japan's lead researcher.

Harnessing the muscle of one of the world's fastest supercomputers, researchers have built one of the largest and most detailed **biophysically realistic brain simulations** of an animal ever. This virtual copy of a whole mouse cortex allows researchers to study the brain in a new way: simulating diseases like Alzheimer's or epilepsy in the virtual world to watch in detail how damage spreads throughout neural networks or understanding cognition and consciousness. It simulates both form and function, with almost **ten million neurons, 26 billion synapses, and 86 interconnected brain regions** (Fig. 1).

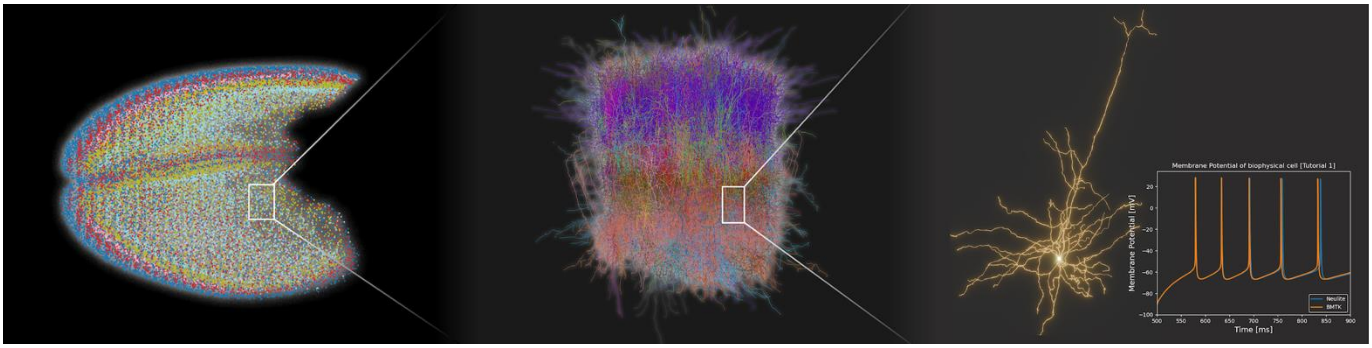

Fig. 1. A mouse whole cortex model simulation on the Supercomputer Fugaku. Left: A whole cortex is reconstructed by arranging biophysical neurons and synaptic connections in a 3D space. Colors represent different cell types. Middle: A local circuit reflects a columnar structure of the cortex composed of 6 layers. Right: Each neuron has its characteristic morphology, ion channels and calcium concentration, thereby exhibiting highly nonlinear dynamics.

This spectacular achievement is the product of Fugaku, the Japanese flagship supercomputer that can crunch data faster than we can blink, with quadrillions of calculations per second. This project was conducted by research teams led by Anton Arkhipov, Ph.D., an investigator of the Allen Institute (USA) and Tadashi Yamazaki, Ph.D., of The University of Electro-Communications, in collaboration with the Research Organization for Information Science and Technology (RIST), Yamaguchi University, and the RIKEN Center for Computational Science (R-CCS). The findings are scheduled to be presented in a paper [1] at SC'25, one of the world's premier international conferences on supercomputing, to be held from November 16-21 in St. Louis, Missouri, USA.

Scientists can use this mouse cortex model to ask detailed questions about what happens in a disease, how brain waves shape focus, or how seizures spread in the brain, and then test their hypotheses. Before this, these questions could only be asked using real brain tissue one experiment at a time. Now, researchers can test hypotheses virtually. Such simulations may also help find answers for brain disorders, revealing how problems begin before symptoms appear, and allow researchers to test new treatments or therapies safely in a digital environment.

"This shows the door is open. We can run these kinds of brain simulations effectively with enough computing power," said Arkhipov. "It's a technical milestone giving us confidence that much larger models are not only possible, but achievable with precision and scale."

This global collaboration merges human neuroscience expertise with the remarkable computing power of a machine. Allen Institute supplied the virtual brain's blueprint and biophysical properties through real data from the Allen Cell Types Database and the Allen Connectivity Atlas and Japan's Supercomputer Fugaku brought the data to life.

How Researchers Created the Whole Cortex Simulation

Fugaku, jointly developed by RIKEN and Fujitsu, is one of the world's fastest supercomputers capable of more than 400 quadrillion operations per second. To put that into perspective, if you started counting right now, one by one per second, it would take over **12.7 billion years** to reach that number (approximately the age of the universe: 13.8 billion years). "Fugaku" comes from Mount Fuji, and just like the mountain's high peak and broad base, it was chosen to symbolize its power and wide reach. "Fugaku is used for research in a wide range of computational science fields, such as astronomy, meteorology, and drug discovery, contributing to the resolution of many societal problems. On this occasion, we utilized Fugaku for a neural circuit simulation," said Yamazaki.

The supercomputer is made up of thousands of small parts called nodes, which are grouped together in layers like units, shelves, and racks. Together, these components add up to a total of 158,976 nodes, allowing Fugaku to manage a massive volume of data and computations. Using the Allen Institute's Brain Modeling ToolKit, the team translated data into the working digital simulation of the cortex. A neuron simulator, Neulite, turned equations into neurons that spike, signal, and chatter just like their living counterparts.

Watching a simulated mouse cortex is like watching biology in real time. It captures the actual structure and behavior of brain cells, down to the branches coming from neurons, the activations of synapses—the tiny contacts conveying messages from upstream neurons to the branches of downstream neurons—and the ebb and flow of electrical signals across membranes. "It's a technical feat, but it's only the first step. God is in the details, so in the biophysically detailed models, I believe," said Yamazaki.

"Our long-term goal is to build whole-brain models, eventually even human models, using all the biological details our Institute is uncovering," said Arkhipov. "We're now moving from modeling single brain areas to simulating the entire brain of the mouse." With this kind of computational power, the goal of a full, biophysically accurate brain model isn't just science fiction anymore. Scientists are in a new frontier where understanding the brain means, quite literally, being able to build one.

This cutting-edge research was made possible by an international team including Laura Green, Ph.D.; Beatriz Herrera, Ph.D.; Kael Dai, B.Sc.; Rin Kuriyama, M.Sc.; and Kaaya Akira, Ph.D.

【Reference】

[1] Rin Kuriyama*, Kaaya Akira*, Laura Green, Beatriz Herrera, Kael Dai, Mari Iura, Gilles Gouaillardet, Asako Terasawa, Taira Kobayashi, Jun Igarashi, Anton Arkhipov, Tadashi Yamazaki. Microscopic-Level Mouse Whole Cortex Simulation Composed of 9 Million Biophysical Neurons and 26 Billion Synapses on the Supercomputer Fugaku, in The International Conference for High Performance Computing, Networking, Storage and Analysis (SC '25), November 16–21, 2025, St Louis, MO, USA. ACM, New York, NY, USA, 11 pages. (*: Equally contributed). doi: 10.1145/3712285.3759819.

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