Digitally reconstructing and simulating the brain
What is the Blue Brain Project?

EPFL's Blue Brain Project is a Swiss brain research Initiative led by Founder and Director Professor Henry Markram.

The aim of Blue Brain is to establish simulation neuroscience as a complementary approach alongside experimental, theoretical and clinical neuroscience to understanding the brain by building the world’s first biologically detailed digital reconstructions and simulations of the mouse brain.

Why is the Blue Brain Project so important?

Understanding the brain is one of the largest Big Data challenges we have today. After years of theory and experimentation, simulation is the evolved phase of many of the sciences and engineering fields. Simulation neuroscience is fundamental to understanding the brain as a complex multi-scale system.

Therefore, the supercomputer-based simulations and reconstructions built by Blue Brain offer a radically new approach for understanding the multi-level structure and function of the brain.

The Human Brain

- Around 100 billion neurons
- 1,000 trillion synapses
- More than one billion molecules in a single cell
- 20,000 genes
- Over 800 different brain regions
- More than 200,000 different proteins

Did you know?

There are more than 600 brain diseases

Understanding the brain is essential to diagnosing and treating neurological disorders (such as Alzheimer’s disease) that are imposing a rapidly increasing burden on the world’s ageing populations.

Promoting open science and collaboration

Blue Brain models, data, online tools and software are available to the neuroscience and broader scientific community through the Blue Brain Portal.

As a research center at École polytechnique fédérale de Lausanne (EPFL), Blue Brain advocates EPFL’s open-science initiative, which seeks to maximize the reach and impact of research conducted at the school.

portal.bluebrain.epfl.ch
How does the Blue Brain Project work?

1. With systemic, industrial-scale collection of experimental data, Blue Brain gathers the information necessary to model the structures and functions of the brain - from the molecular level to neurons, synapses, circuits, brain regions and eventually the whole mouse brain.

2. Interdisciplinary teams of neuroscientists and computer engineers perform complex steps to recreate biologically-realistic digital in silico models which are validated against data to improve accuracy.

3. In parallel, Blue Brain’s main activities — neuroinformatics, digital reconstruction of neural tissue, simulation, data analysis and scientific visualization — are powered by Blue Brain’s supercomputing infrastructure and continuously updated through validation and analysis.
Blue Brain’s major findings

In 2015, Blue Brain reached a major milestone with the publication of a first draft of the digital reconstruction of neocortical microcircuitry (Markram et al, 2015). The study confirmed the feasibility of building and simulating a digital copy of a part of the brain and demonstrated that multidisciplinary Big Science in the field of neuroscience yields favorable results (82 scientists contributed to the study).

The paper, which appeared in the journal Cell, represents the most complete description of any neural microcircuit to date. It provides a complete digital map of all the cells and synapses in a block of neural tissue and describes simulation experiments replicating a range of previous in vivo experiments. In other words, Blue Brain’s digital copy of a part of the brain behaves like a real part of the brain.

Most significantly, this study advances the case for simulation as a useful new method in neuroscience. It proves that we understand the basic properties of the components and interconnections of the brain well enough to be able to reconstruct and simulate certain physiological functions.

Consequently, Blue Brain has now:

- **Built** a digital copy of the whole somatosensory cortex with around four million neurons, a part of the hippocampus (a brain region that serves as our GPS system in the brain) and a microcircuit of the thalamus (a part of the brain that organizes all the information that goes to and from the neocortex).

- **Produced** the first draft model of the rules guiding neuron-to-neuron connectivity of a whole mouse neocortex. Based on these rules, the team has generated statistical instances of the micro-connectome of 10 million neurons, a model spanning five orders of magnitude and containing 88 billion synaptic connections that will serve as the basis of the world’s largest-scale simulations of detailed neural circuits.

- **Released** the Blue Brain Cell Atlas - the first digital 3D atlas of every cell in the mouse brain. This provides neuroscientists with previously unavailable information on major cell types, numbers and positions in all 737 brain regions.
Translational research
Furthering Blue Brain’s current research strengths, driving translational research with a focus on applications of neurological disorders, neurotechnologies and machine learning.

Dissemination
Continuing to provide data, models, open source software and online tools to the scientific community through the Blue Brain Portal and as a collaborator on the platforms of the European Human Brain Project. Blue Brain is catalyzing community collaboration on reconstructing and simulating biologically detailed models of the brain.

What next?

1. Science
   Building larger areas of the mouse brain - the neocortex and its connecting brain region, the thalamus and at higher resolution (the molecules inside of each cell).

2. Translational research
   Furthering Blue Brain's current research strengths, driving translational research with a focus on applications of neurological disorders, neurotechnologies and machine learning.

3. Dissemination
   Continuing to provide data, models, open source software and online tools to the scientific community through the Blue Brain Portal and as a collaborator on the platforms of the European Human Brain Project. Blue Brain is catalyzing community collaboration on reconstructing and simulating biologically detailed models of the brain.

Blue Brain has published more than 185 papers and pre-prints in international journals.

- Mapped the kinetic behavior of the largest family of ion channels: Kv channels and provided open access to the million-plus Kv channel recordings from over 18,000 cells, and a growing dataset for other channels. These are publicly available for download on the dedicated, wiki-like platform Channelpedia. channelpedia.epfl.ch.

- Helped other groups to build digital copies of other brain regions.