Introduction to Digital Brain Models

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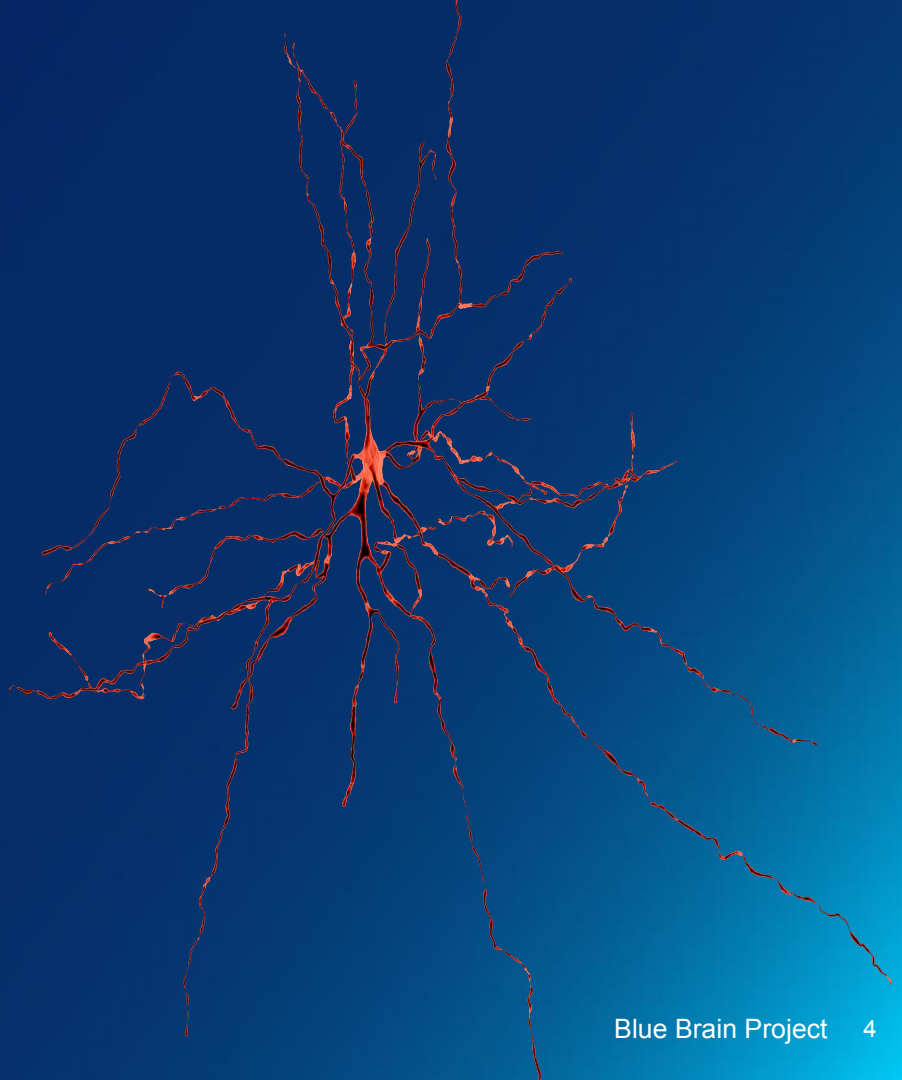
Ion channels

- Ion channel models describe the kinetics of a type of membrane-bound ion channel upon depolarization or hyperpolarization.
- They were automatically sampled at different temperatures to be able to systematically study the effect of temperature.

Single Neuron

- Single neuron models describe the shape and physiology of neurons.
- Shapes or morphologies are described as trees of cylindrical compartments.
- The physiology or electrical behavior emerges from modeled distributions of ion channels over the morphology.
- Single neuron models can be readily simulated under various conditions to yield time series of the voltages of every part of their morphology.



Paired Neurons

- A paired neuron model comprises two single neuron models and a description of the synaptic contacts between them.
- The synapses between them are selected from locations where synapses can potentially form, based on proximity of the axon of one cell and the dendrite of the other. That means that these models always describe anatomically plausible situations.
- Physiologically, synapses include models of their short-term kinetics, transmission failures, vesicle depletion, calcium-dependence, and optionally, their functional plasticity.
- Paired models can be used, for example, to study the reliability of various pathways under different calcium conditions.

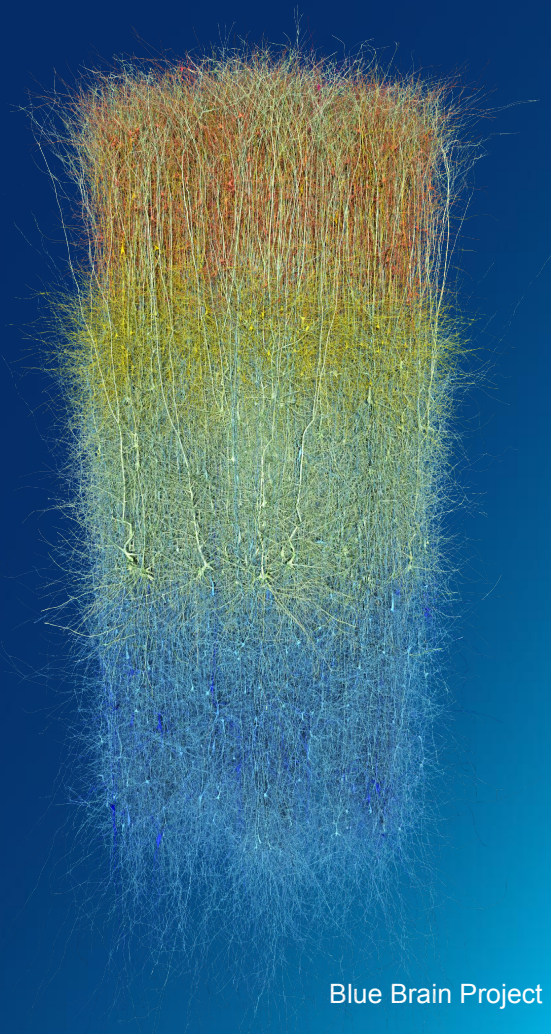
Synaptome Neuron

- A synaptome model comprises a single neuron model and models of its afferent synapses.
- Afferent synapses model the same biophysical detail as for paired neuron models.
- Their locations are the predicted location from a brain region model, or distributed algorithmically, or a combination of both.
- In simulations, synapses can be activated at will to study their interactions, as they occur, for example, during plasticity.

Microcircuit

31K neurons - 37M synapses

- A cortical microcircuit model comprises all six cortical layers with a horizontal extent that captures the entire dendritic tree of the most central neurons.
- Neurons within have the same anatomical and physiological level of detail as single neuron models.
- All synapses between the contained neurons are included, plus more abstract models of thalamo-cortical axons that serve as user-controlled inputs.
- This setup can be used to study the local processing of thalamic inputs, and the roles of individual subpopulations during that process.



Brain Area

217K neurons

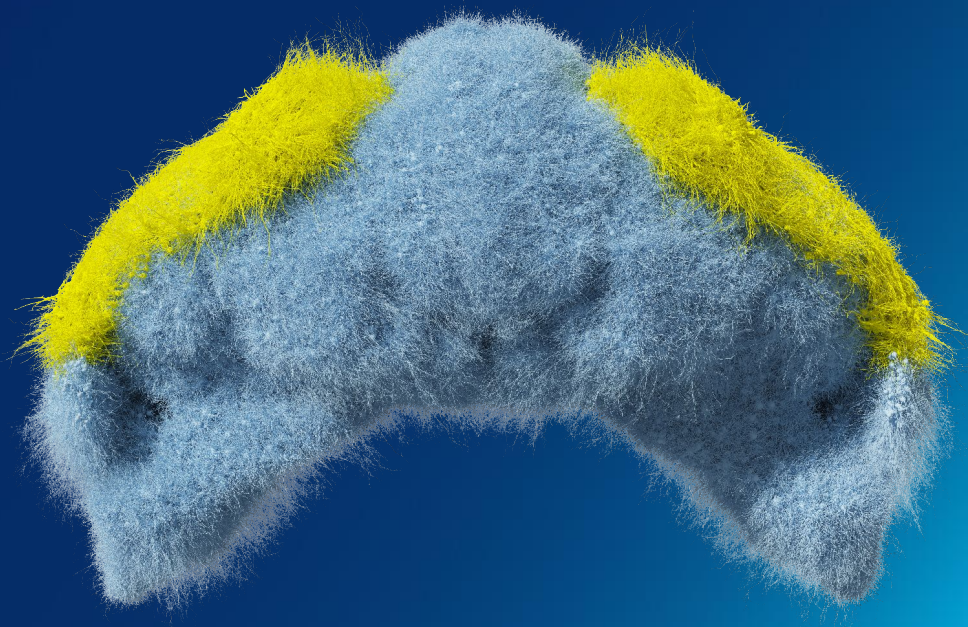
- This is similar to a microcircuit, but larger; offers the opportunity to study processing over larger spatial scales.

Brain Regions - Thalamus

331K neurons - 40M synapses

This is a model of three thalamic nuclei: VPM, POm, and RT.

- As all brain region models, it is constructed in a volumetric atlas and hence takes the shape of the modeled regions into account.
- Within the atlas, neurons are placed according to experimentally measured cell densities.
- The entirety of the model can be simulated, or user-specified parts of it.
- The model can be used to study the anatomy and activity of this pivotal brain region.



Brain Regions - Hippocampal CA1

460K neurons - 800M synapses

This is a model of the CA1 regions of rodent hippocampus

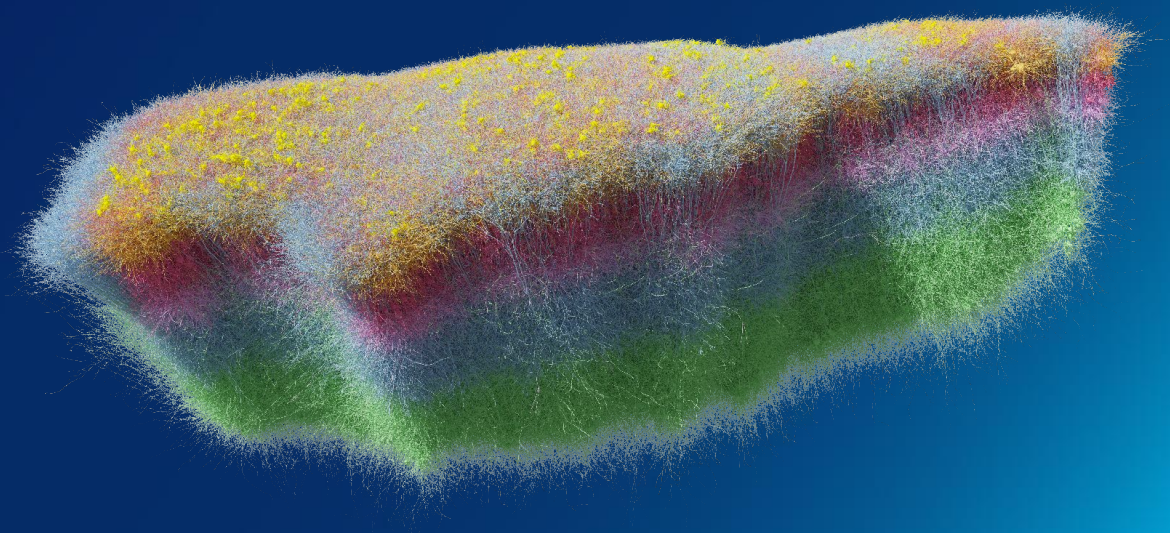
- ✓ constructed in a volumetric atlas
- ✓ takes the shape of the modeled regions into account
- ✓ neurons placed according to experimentally measured cell densities
- ✓ entirety or user-specified parts of the model can be simulated
- ✓ facilitates the study of both the anatomical structure and neural activity in this brain region

Brain Regions - Non Barrel Somatosensory Cortex

1.7M neurons - 4.7B synapses

This is a model of the non-barrel somatosensory regions of rodent cortex

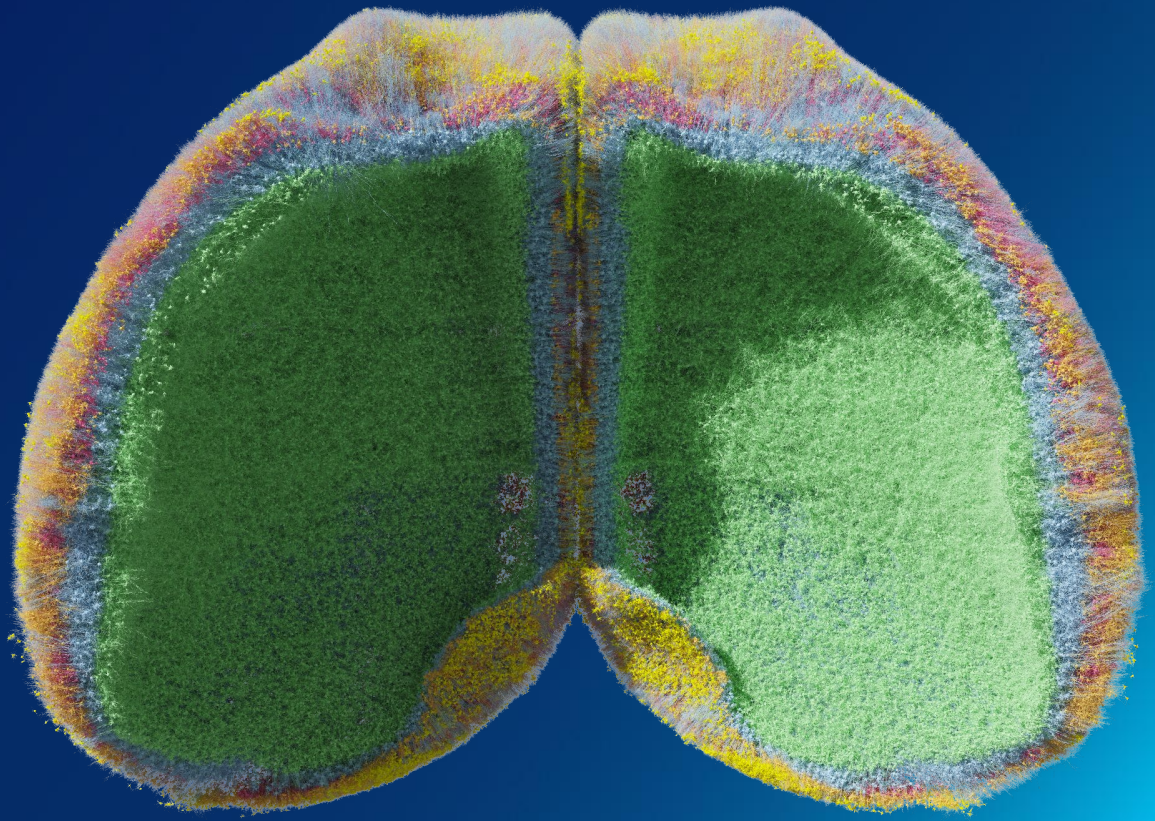
- ✓ constructed in a volumetric atlas
- ✓ takes the shape of the modeled regions into account
- ✓ neurons placed according to experimentally measured cell densities
- ✓ entirety or user-specified parts of the model can be simulated
- ✓ facilitates the study of both the anatomical structure and neural activity in this brain region



Brain Regions - Neocortex

10.7M neurons - 88B synapses

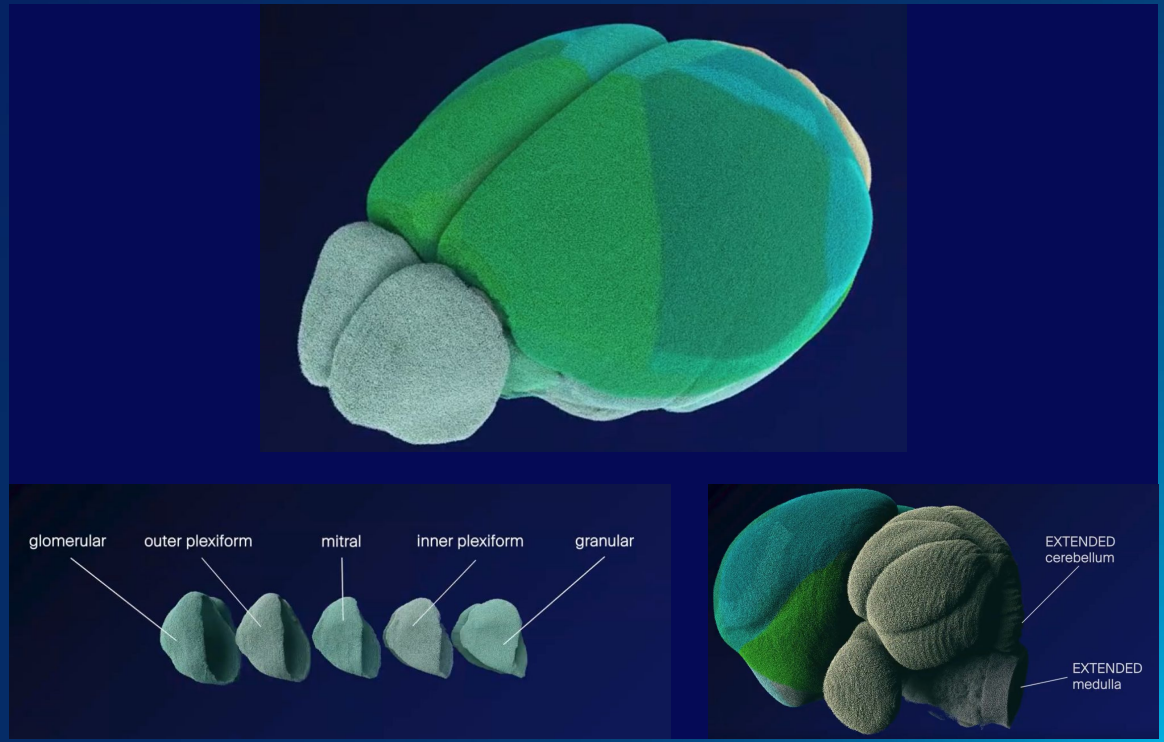
- Building upon the somatosensory cortex model, this extends the work to cover all regions of mouse neocortex.
- It can be analyzed or simulated in its entirety, or selected regions only.
- As such, it can be used to study the dynamic interactions between the various regions.



Whole Brain with Olfactory Bulb and Cerebellum

71.5M neurons

- This extremely large model combines the neocortex model with models for the various other parts of the brain.
- The models for the olfactory bulb and cerebellum were constructed in collaboration with experts from the community to accurately capture their specific anatomy and physiology.

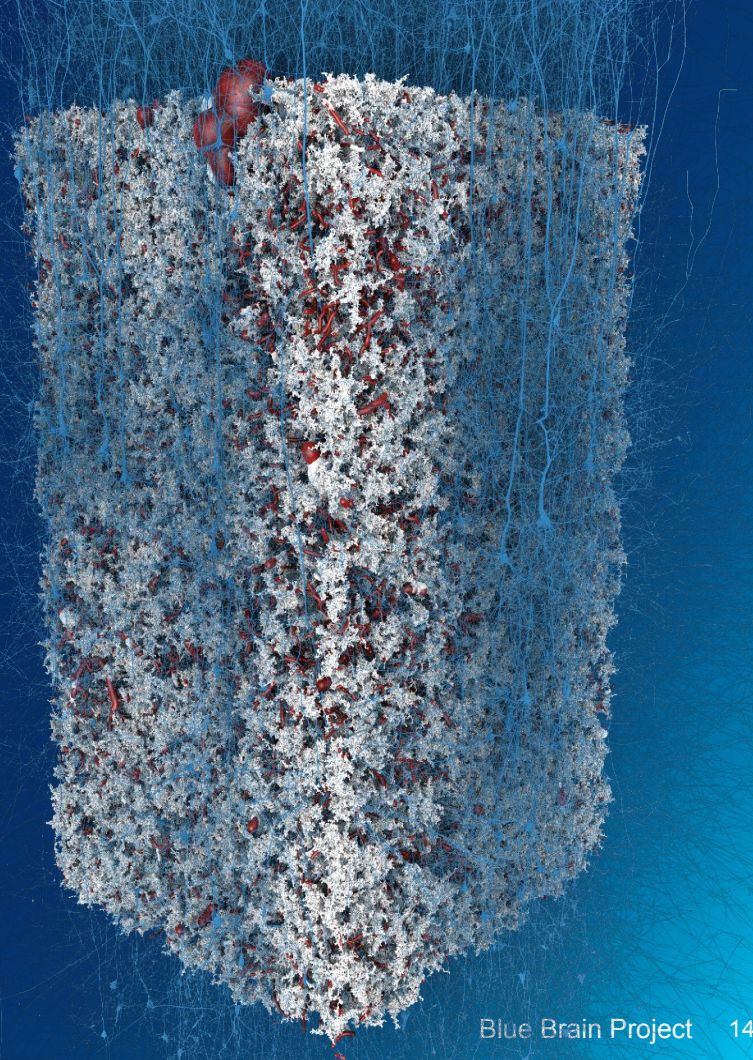


Neuro-glia-vascular System

88K neurons - 14K astrocytes - blood vessel

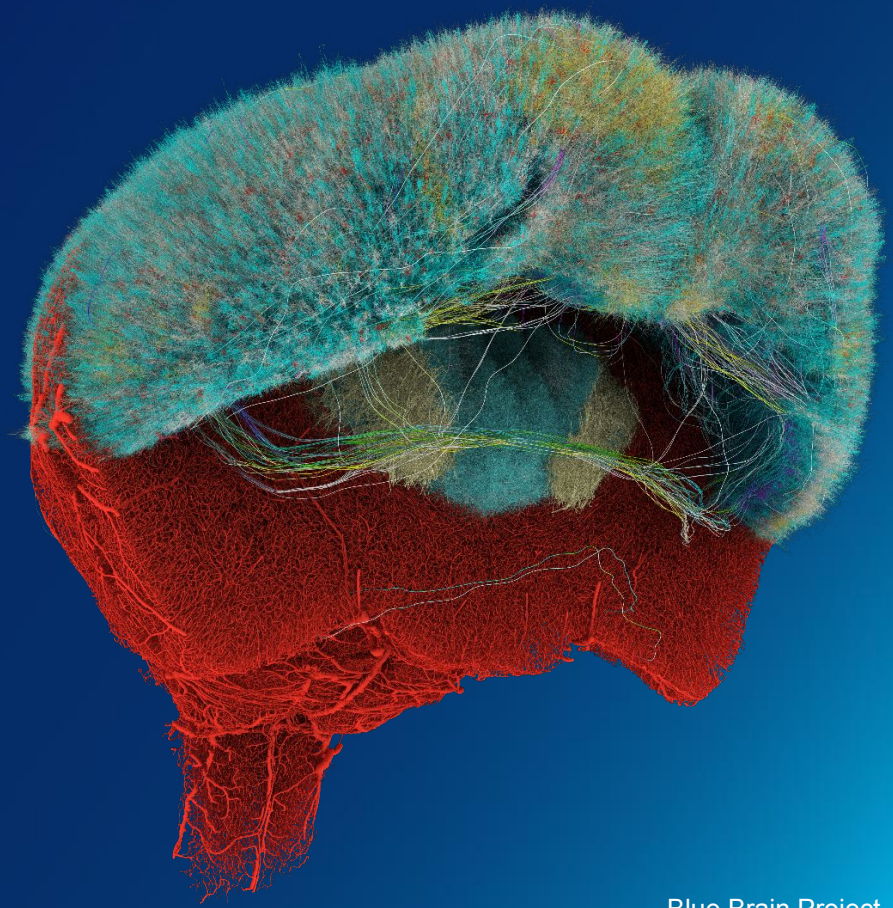
- This enhanced model combines a microcircuit model with
  - models of astrocytes in biological densities
  - blood vessels innervating the volume

- The dynamic interactions between neurons, the astrocytes and the vascular system are also modeled and can be readily simulated to gain a deep insight into their functionalities.



Brain Vascular System

- This scaled-up version of the model of the neuro-glia-vascular system encompasses the whole brain.



Thank you!

www.epfl.ch/research/domains/bluebrain

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