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EBRAINS Research Infrastructure, leveraging the power of data to decode the complexity of the brain

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3rd ESFRI Open Session - 80th ESFRI Plenary

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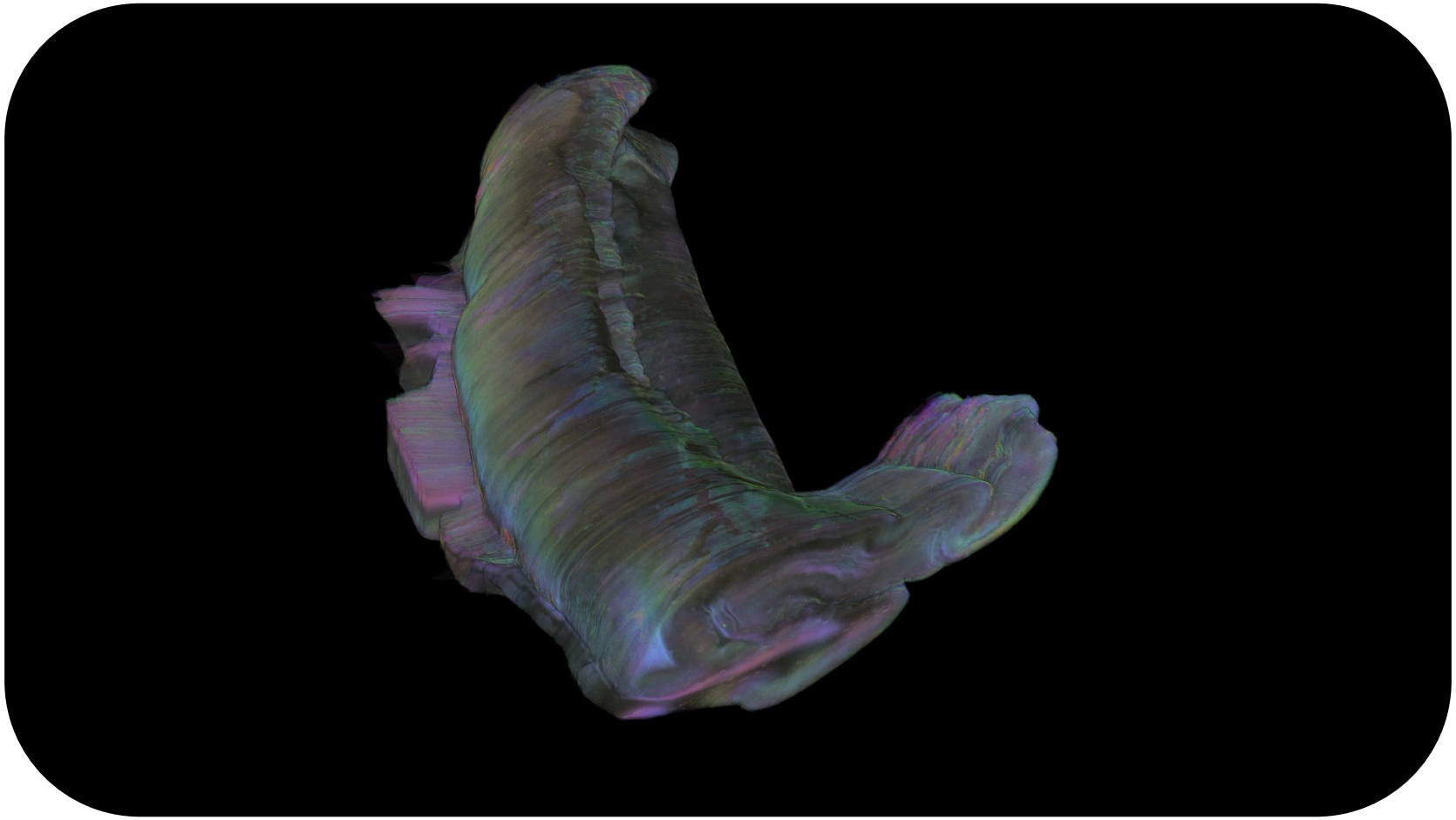
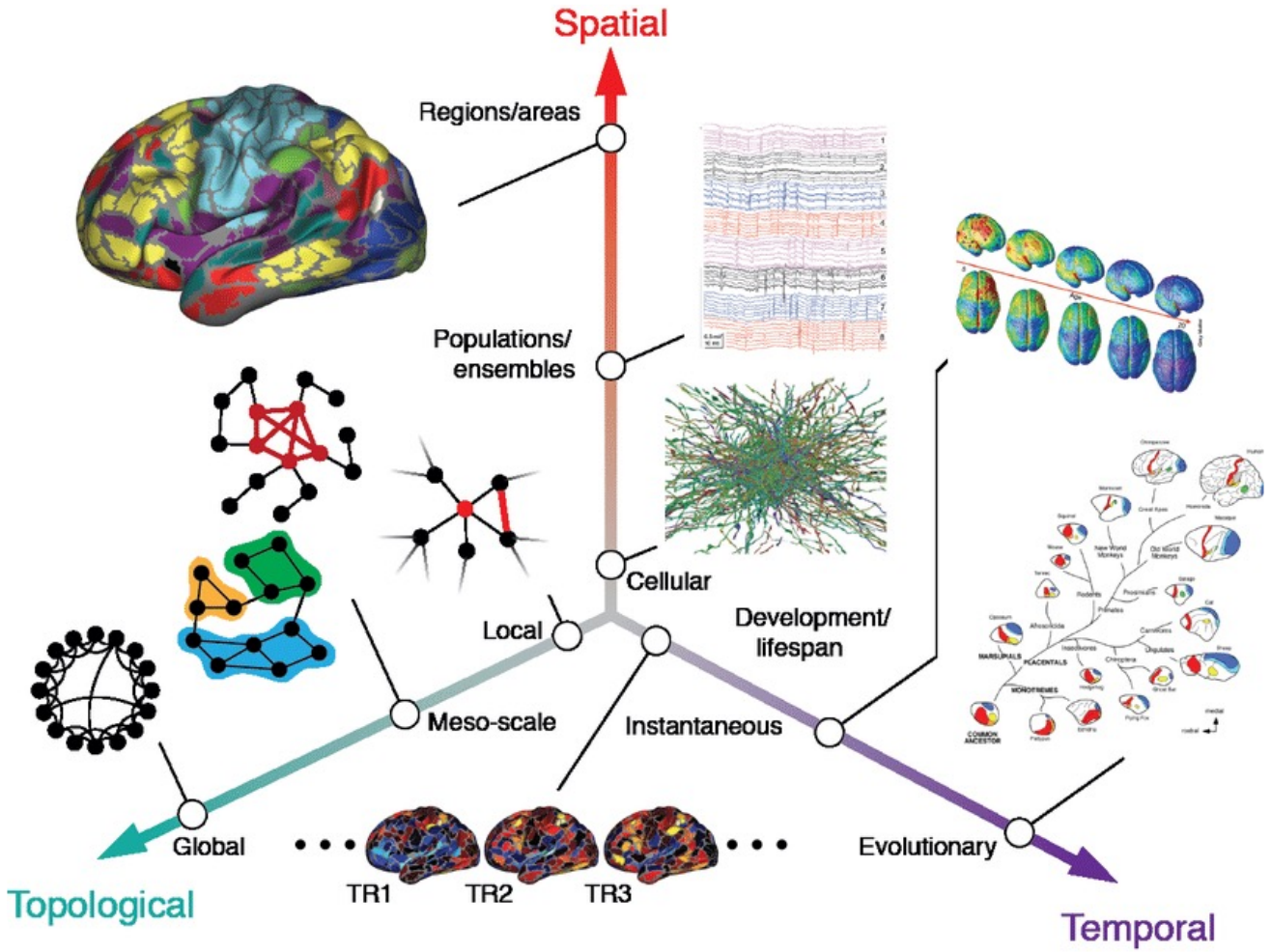
The Brain is one of the most complex data systems



3D-reconstruction of the human hippocampus based on 3D-Polarized Light Imaging based on 530 sections (80 GByte)
(Axer, Amunts et al. @FZ Jülich)

Decoding multiscale organization of the brain



The Human Brain in numbers

- Estimated number of nerve cells: about 86 billion, approximately the same number of glial cells, about 10.000 synapses per neuron. For comparison, a galaxy has about 100 billion stars.
- Type of signal transduction: electro-chemical, while digital computers use electrical signals.
- Total length of connections: 2-3 million kilometres of fibers - this is more than the diameter of the sun with 1.4 million kilometres
- Mass: 1200 – 1500 g, about 2% of the body weight
- Energy consumption: 20-30 Watt, i.e., about 20% of the total energy consumption of the body

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Estimates for computational demands to study the human brain

- An anatomical 3D model @ 1 micron resolution isotropic needs 2-3 PByte storage per brain
- Neuronal network training to extract structural features in images with a spatial resolution of 1x1x20 microns would require, for the whole brain, 100 days at whole brain level with current technology
- A 10 seconds point-neuron simulation including 4 million neurons requires 10 minutes of computation on EBRAINS' Fenix system (400 core hours)
- One second of simulation of a network of 450,000 cells with a high level of details of the hippocampus CA1 region requires at least 20,000 cores and needs 130,000 core hours on the Piz Daint supercomputer at CSCS.

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Decoding human brain connectome – enormous challenge for compute and storage technologies

Science

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Brain research challenges supercomputing

Big data obtained from unraveling human brain structure raise processing demands

KATRIN AMUNTS AND THOMAS LIPPERT

SCIENCE · 25 Nov 2021 · Vol 374, Issue 6571 · pp. 1054-1055 · DOI: 10.1126/science.abl8519

Abstract

The adult human brain contains ~86 billion neurons (*1*). Zooming into its cellular and subcellular details to reveal different aspects of neuronal connectivity is a key area of research. However, to link the different spatial scales from the synaptic level (at nanometer range) through single neurons and glial cells (at the micrometer level) to the whole organ is most challenging. Recently, the connectome of *Caenorhabditis elegans*, with its 302 neurons, has been characterized, and a complete structural-functional model has been proposed (*2*). A comparable level of detail of the human brain connectome is still a long way off. As such, decoding the human connectome, the mechanisms of signal transduction, and relationships to brain function are linked to exponentially growing challenges in advanced computational and storage technologies, which in turn may lead to creative solutions beyond neuroscience.

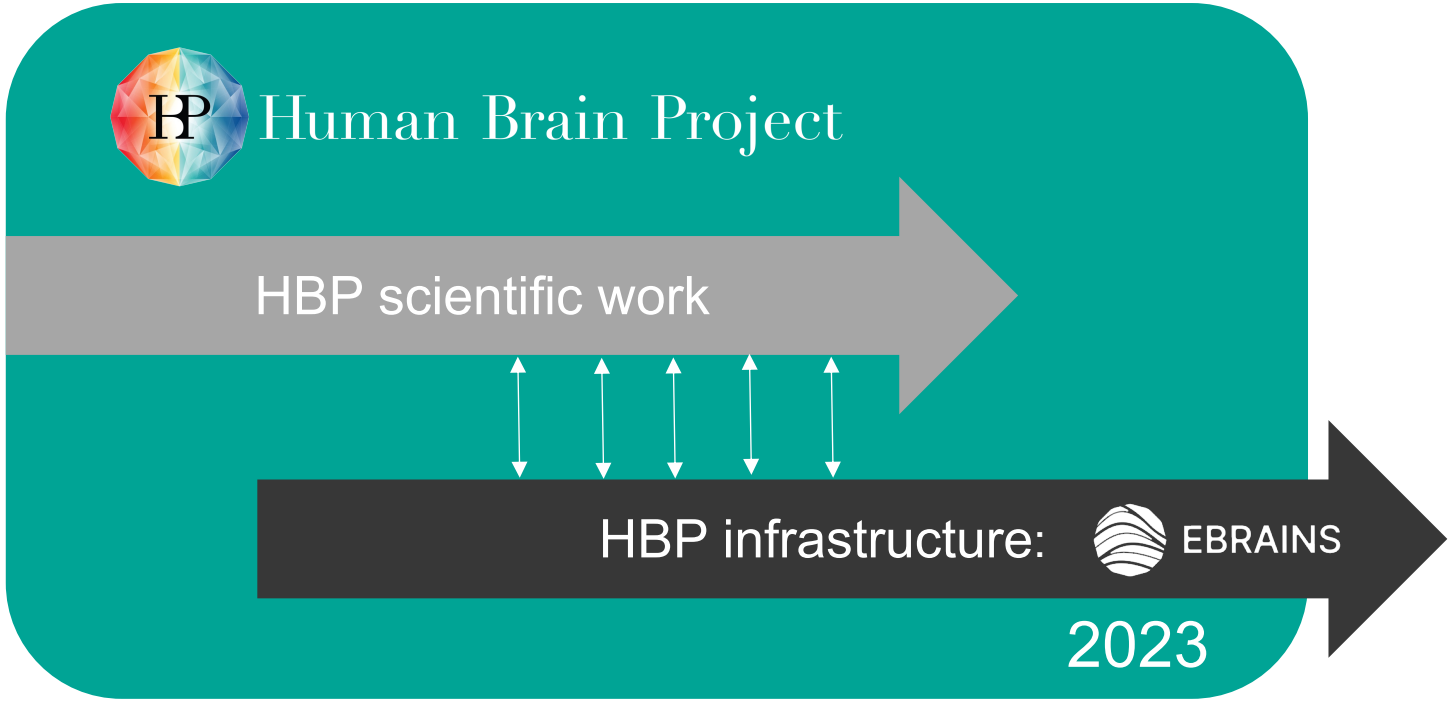
Digital data and the capacity to process it hold the greatest promise of delivering scientific breakthroughs, including diagnostic and therapeutic progress

EBRAINS' mission: Enabling brain research advances and innovation

EBRAINS builds **on the work of the Human Brain Project and takes it to the next level**

EBRAINS offers the science community **state-of-the art**

- Brain data
- Simulation and modelling tools
- Access to (super) computing resources



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EBRAINS offers a focused and deep range of services

EBRAINS aims at **accelerating collaborative brain research** with a comprehensive package of data, tools and facilities.

Data and Knowledge

Online solutions to facilitate sharing of and access to research data, computational models and software

Atlases

Navigate, characterise and analyse information on the basis of anatomical location

Simulation

Solutions for brain researchers to conduct sustainable simulation studies and share their results

Brain-Inspired Technologies

Understand and leverage the computational capabilities of spiking neural networks

Medical Data Analytics

The Medical Data Analytics service provides two unique EBRAINS platforms, covering key areas in clinical neuroscience research

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Value added of EBRAINS as a Research Infrastructure

Fair & high-quality data

- Unique degree of data findability
- Both, machine and human readable metadata
- Use of OpenMINDS meta data schemas
- Curation by expert neuroscientists
- Access restriction to be defined by individual
- Links to interactive Brain Atlas

Collaboration, co-design and user support

- Technological development is driven by concrete scientific questions and use cases
- More documentation and higher TRL than most of the scientific software
- Efficient support of users through the High-Level Support Team
- Partnering projects
- Systematic analysis of feedback and updates

Unlocking the value of data requires…

… creating a virtuous cycle

Reuse leads to standards and standards lead to reuse

We need to accompany the journey and amplify what the researcher is working with

Developing solutions with the use of high-end analytics

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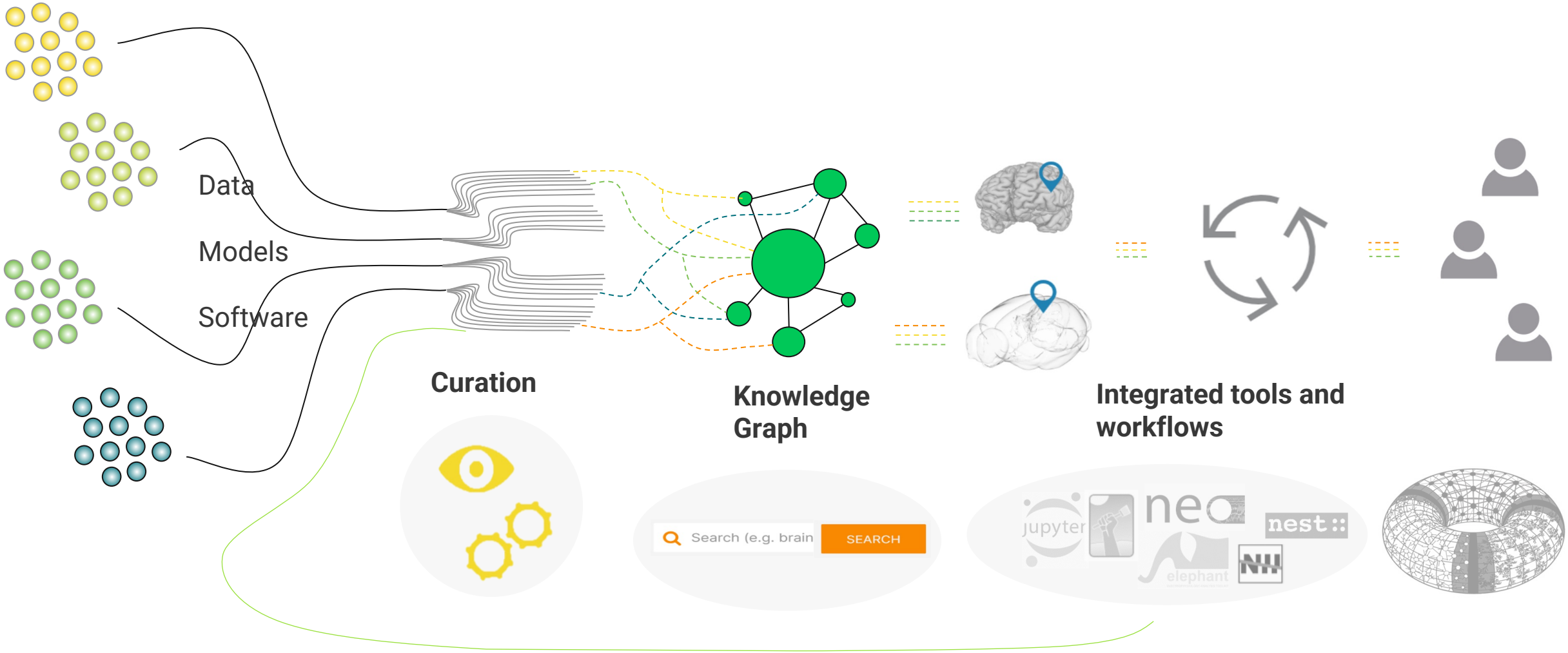
EBRAINS workflow example: “Share – Find – Use”



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Ecosystem of neuroinformatics tools to enable complex in-silico experiments

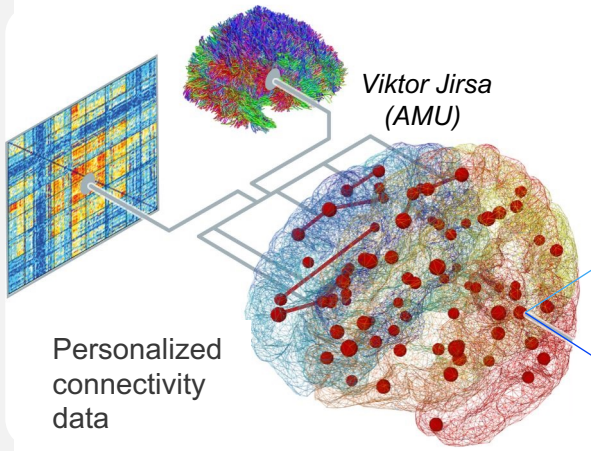
Multi-simulator interaction

Multi-simulator interaction

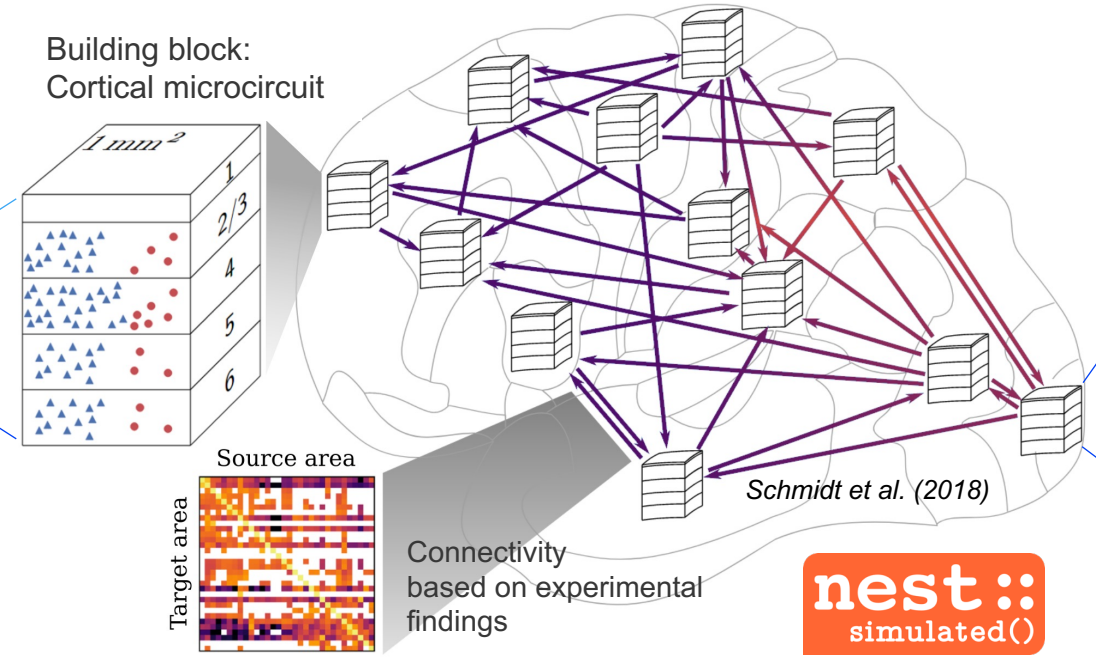
Brain models at brain-region resolution

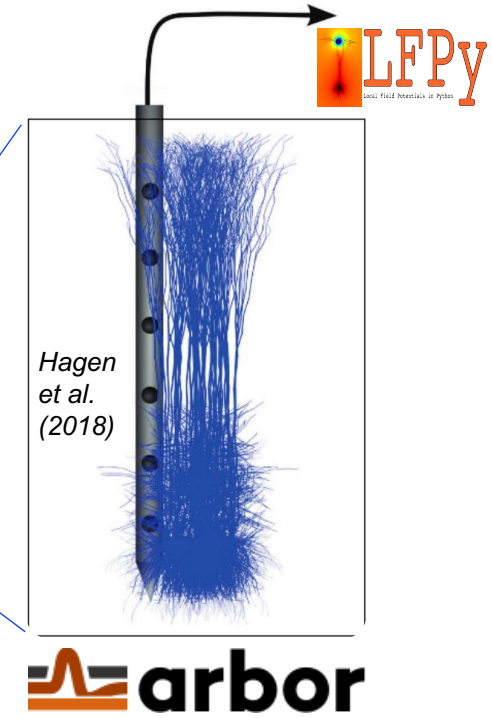
Brain-scale models at single neuron resolution

Cortical circuits with morphological details



THEVIRTUALBRAIN.





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EBRAINS data amplification capacity

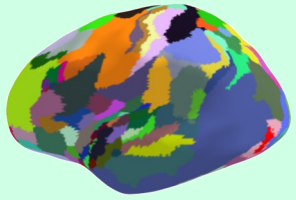
High performance computing enables high-resolution individualization and extension to modelling cohorts

Clinical decision support tools tailored to the individual, applied in clinical trials

Multiscale integration to identify key mechanisms that predict disease progression for novel therapeutic solutions

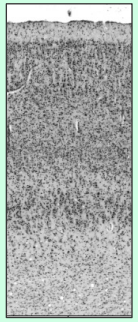
Degeneracy in neuroscience - when is Big Data big enough?

Data collection

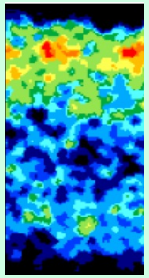


Cytoarchitectonic maps

Structural & functional connectivity

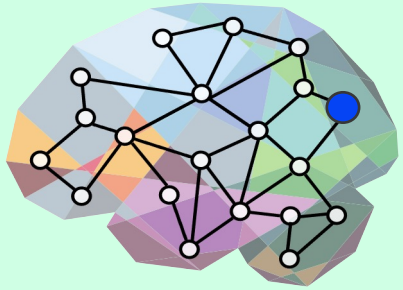


Cell densities



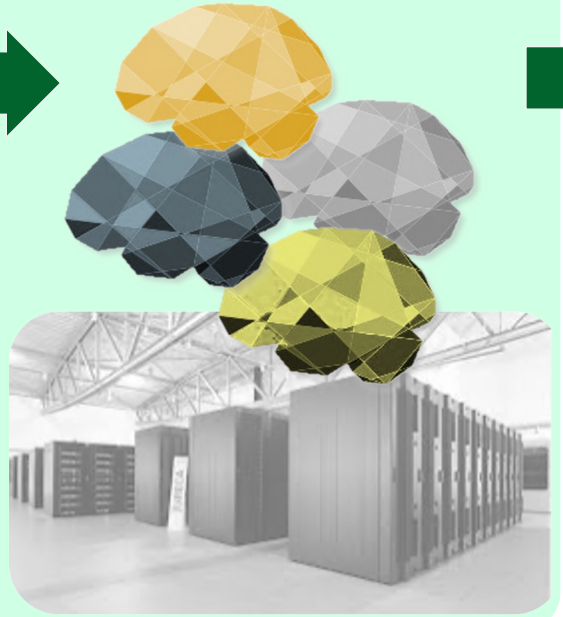
Receptor densities

Model construction

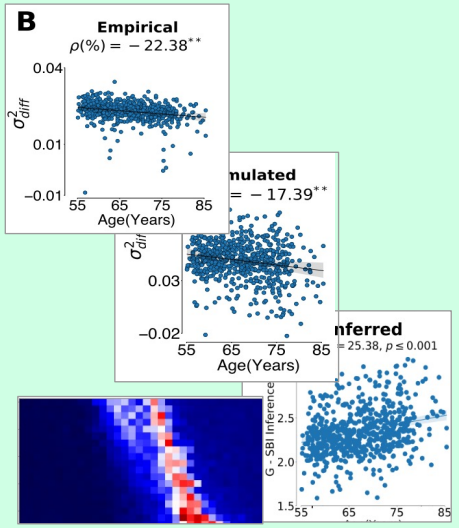


TVB: Brain Network Model

Optimization & Inference



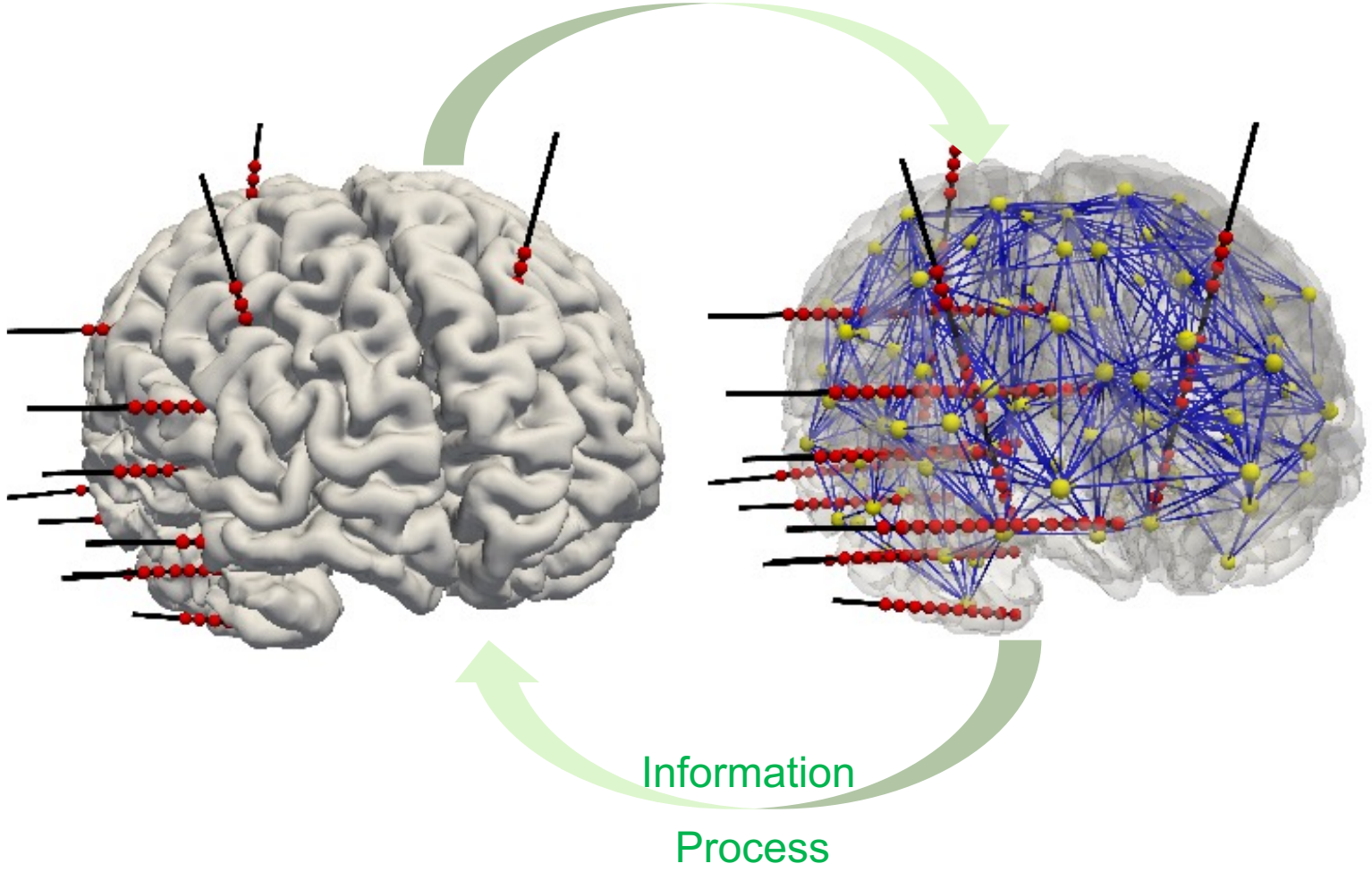
Visualization & Analysis



HBP/EBRAINS' scientists are working on demonstrating that cutting edge datasets on structural variability can be used to explain functional variability of age effects with whole brain models.

Towards Digital Twin technology

Virtual models designed to adequately represent an object or process that **is constrained by data** from its physical counterpart, and that **provides simulation data to guide choices and anticipate their consequences**.



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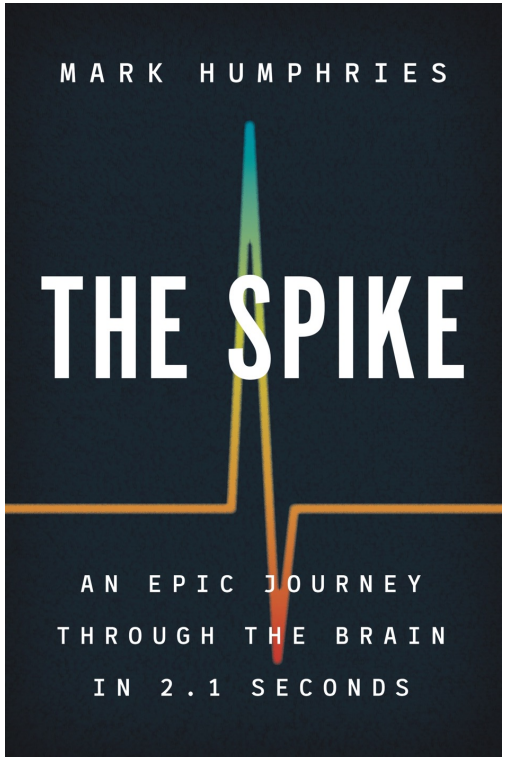
Simulation: quest to explore complexity

Almost everything we will know in 100 years' time will be from simulation. We will have a set of agreed principles, algorithms for learning. But for sticking them together, we will need simulation.

Mark Humphries, author of "The Spike"



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Tackling the sensitive data challenge in brain research

HDC
HealthDataCloud

EBRAINS HealthDataCloud will provide a GDPR-compliant, federated research data ecosystem that enables research consortia across Europe and beyond to work with sensitive brain data originating from human subjects, as well as defined routes for sharing of the data and results.

Causal inference exploits patient-specific brain models to develop diagnostic solutions for early detection of neurodegeneration

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Step-change in accessibility: European Health Data Space

- ✓ Common European approach for the use and re-use of health data that complements and builds on the GDPR
- ✓ 15 mandatatory categories of data to be defined
- ✓ Data access bodies to be set up to provide access in a secure environment
- ✓ One request to be sufficient for all required data sets in the different European countries
- ✓ **Pilot project planned to prepare and test infrastructural support**

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Thank you

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