Human Brain Project

Human Brain Project

Unifying our understanding of the human brain

Co-funded by
the European Union

The Human Brain Project – An **ICT** Flagship

Understanding the human brain is one of the **greatest challenges** facing 21st century science. If we can rise to this challenge, we can gain **profound insights** into what makes us human, build **revolutionary computing technologies** and develop new **treatments for brain disorders**.

Today, for the first time, modern Information and Communication Technology (ICT) has brought these goals within reach.

http://flotillafacts.com/wp-content/uploads/2015/11/Santa_Maria.jpg

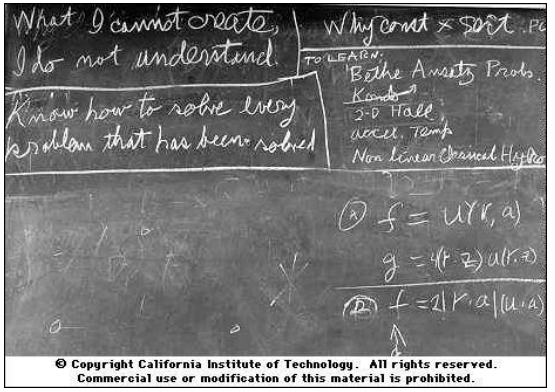
The Vision of the Human Brain Project

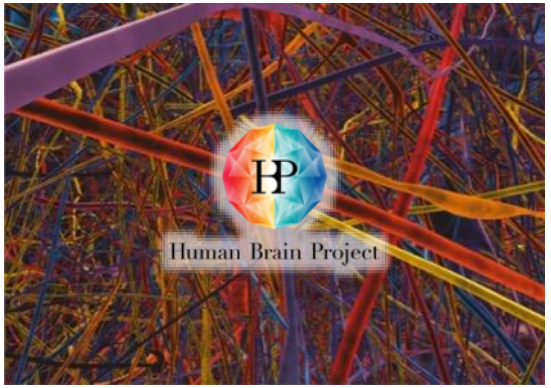
R. Feynman : “**What I cannot create I do not understand”**

To **understand the brain** we need a

- large-scale, interdisciplinary, **integrating infrastructure**
- for performing **holistic multi-level** studies of brain **and** body
- from **analytics** and **neuroscientific data** by way of synthetic **modeling** for partial/full brain **simulation**, brain model **reconstruction**
- to design new **computer architectures** and **robots**.

HBP is a **European FET Flagship project** to **create** and **operate** collaborative research tools for **experimental** and **virtualized brain research**, and for developing **brain-derived technologies**.





FET-Flagships: History and Concept

- In 2009, the EU ICT Advisory Group recommended that the EC implement a new funding scheme to make Europe a major player in **big, high-risk, <u>focused</u> research projects in ICT.**
- As the result of a competitive call for proposals, 23 proposals were submitted in December 2010.

Objective ICT-2011.9.5:

FET Flagship Initiative Preparatory Actions

FET Flagship Initiatives are science-driven, large-scale, multidisciplinary research initiatives oriented towards a unifying goal and nucleated from ICT future and emerging technologies. The goals of such initiatives should be visionary and highly ambitious, requiring cooperation among a range of scientific disciplines and research topics going beyond the ICT programme. FET Flagship Initiatives are envisioned to be long term programmes on a scale much beyond current FET Proactive Initiatives. The overarching nature and magnitude implies that they can only be realised through a federated effort of key stakeholders, building on European excellence. Specific aspects to consider are:

- **Mission:** the unifying goal should be a clearly formulated and broadly accepted long term vision involving major challenges in science and technology, requiring a large federated effort, and justified via comparison with existing activities and state of the art
- **Impact:** a clear leverage effect, substantial progress and major innovation in science and technology; affecting competitiveness of European industry, society, governance and sustainability, considering potential ethical and legal implications
- **Integration:** an operational framework describing how relevant disciplines, stakeholders and resources will be brought together at European or larger scale, and how they can be efficiently coordinated under strong scientific leadership along a cohesive roadmap with reasonable milestones that mark valuable interim results

Target Outcome

a. Complete design and description of a consolidated candidate FET Flagship Initiative, including assessment of feasibility in scientific, technical and financial terms, i.e. with a well-defined goal thoroughly justified in terms of scientific advance and impact, implementation plan, an operational framework, the identification of resources, maturity, capacity, clear evidence of commitment from key stakeholders (in particular scientific communities, Member States and Associated Countries, funding agencies and global partners) with adequate level of integration and identity of the supporting community, and the development of an integrative research agenda to enable the launch of a FET Flagship by 2013. The objective is to support in the order of 5-6 projects,

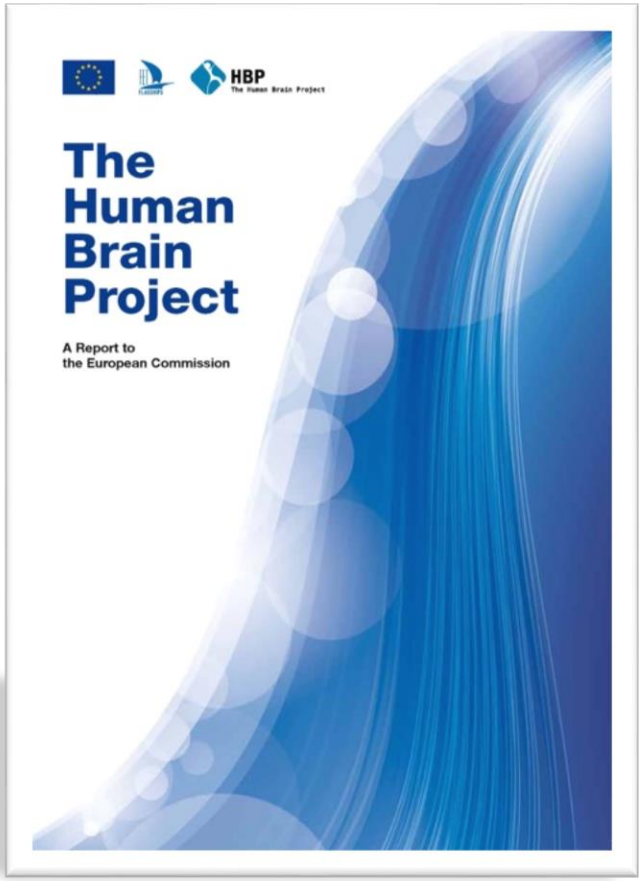
http://cordis.europa.eu/fp7/ict/programme/fet/flagship/doc/press-17_en.pdf /

FET-Flagships: History and Concept

- In March 2011, six candidates were selected for a **pilot phase** for writing a full proposal – and two were finally selected in January 2013.
- Submitted Proposals:
  1) FuturICT – Knowledge Accelerator and Crisis-Relief System
  2) **Graphene Science and technology for ICT and beyond**
  3) Guardian Angels for a Smarter Planet
  4) **The Human Brain Project**
  5) ITFoM: The IT Future of Medicine
  6) RoboCom: Robot Companions for Citizens

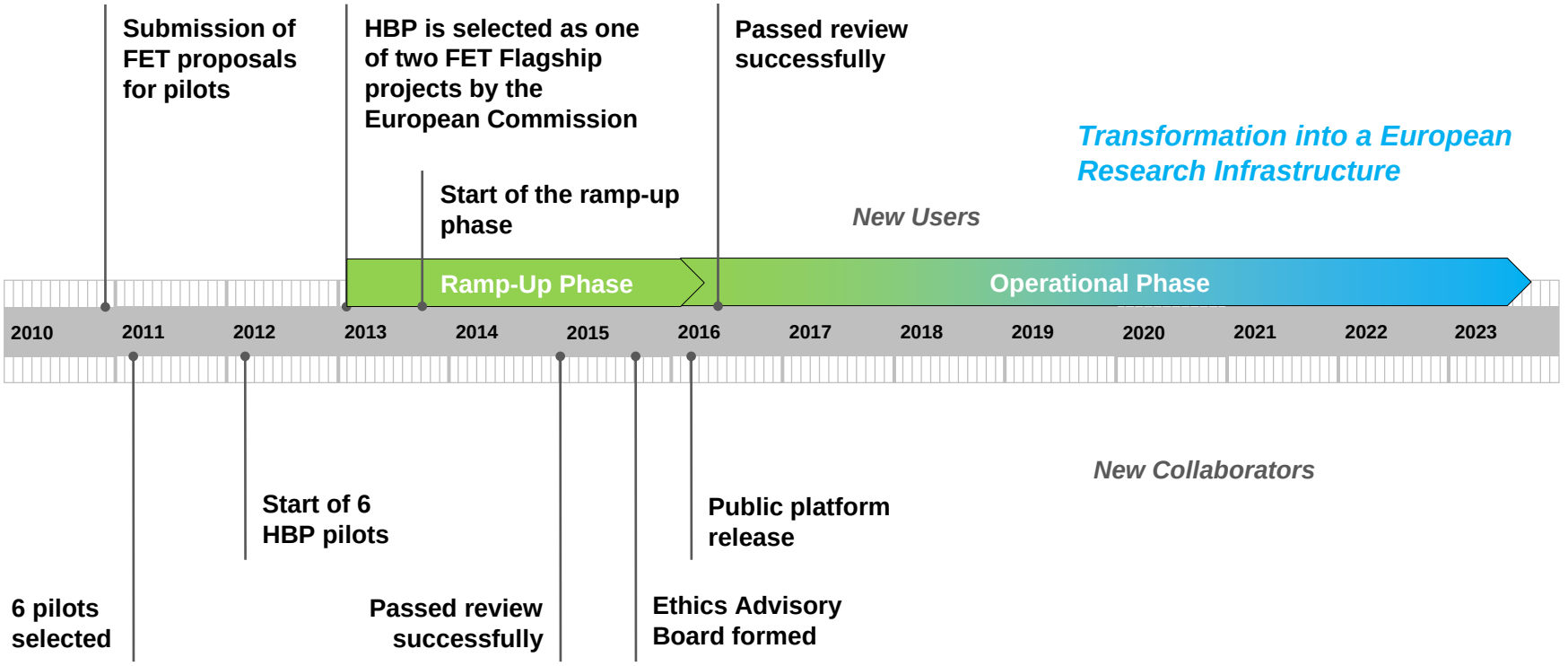
HBP is an **open project** and allows new contributing partners to work with the core consortium.

HBP started on **1 October 2013.**



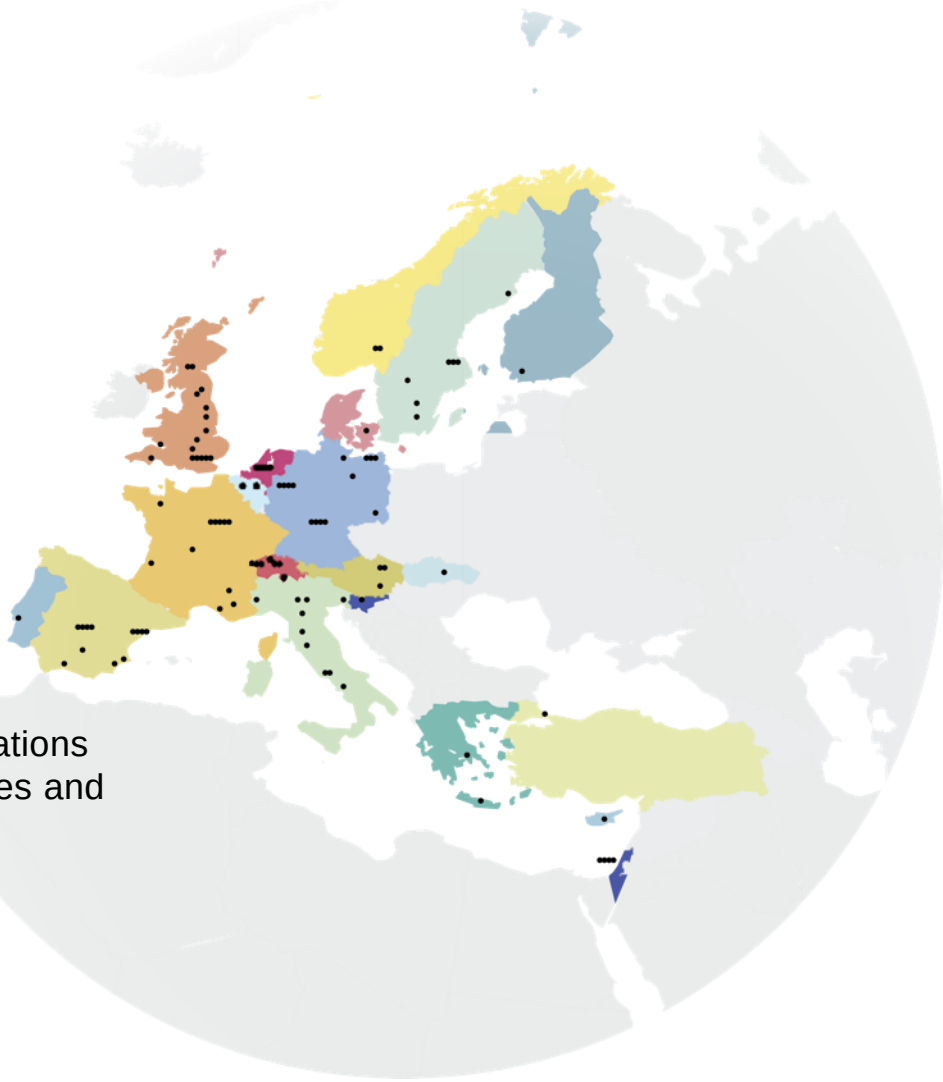
https://www.humanbrainproject.eu/documents/10180/17648/TheHBPReport_LR.pdf

Project Timeline



HBP at a Glance – Facts and Figures

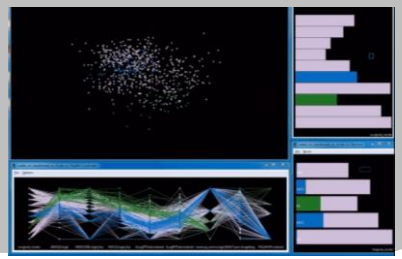
- 10 year, EUR 1 billion research roadmap (50% Core Project, 50% Partnering Projects)
- Core project 400+ scientists, 116 institutions, 19 countries
- 6 prototype infrastructure platforms released in March 2016
- Embedded in previous and existing national and international initiatives: Blue Brain, BrainScaleS, Supercomputing and Modeling the Human Brain, SpiNNaker, PRACE, etc.
- 23 industry collaborations; 121 research collaborations with non-HBP research groups (61 with universities and institutes in 3rd countries)



Research Branches within the Human Brain Project

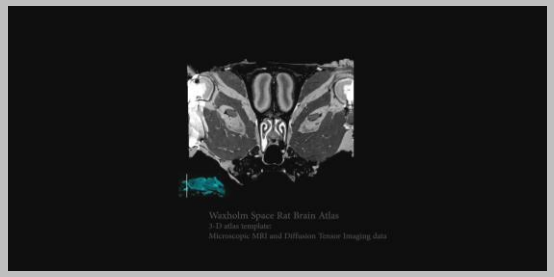
Accelerating Medicine

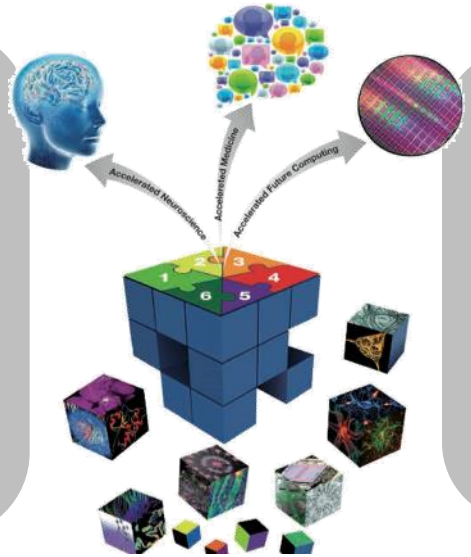
Contribute to understanding, **diagnosing** and **treating diseases** of the brain.



Accelerating Neuroscience

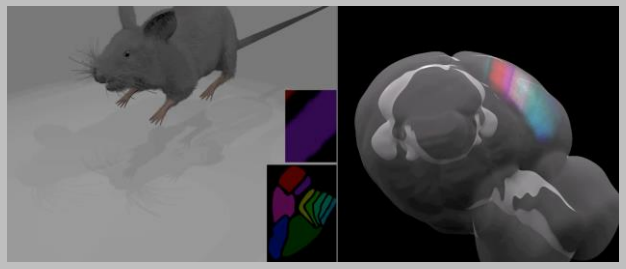
Integrate everything we know about the brain into **computer models and simulations**.



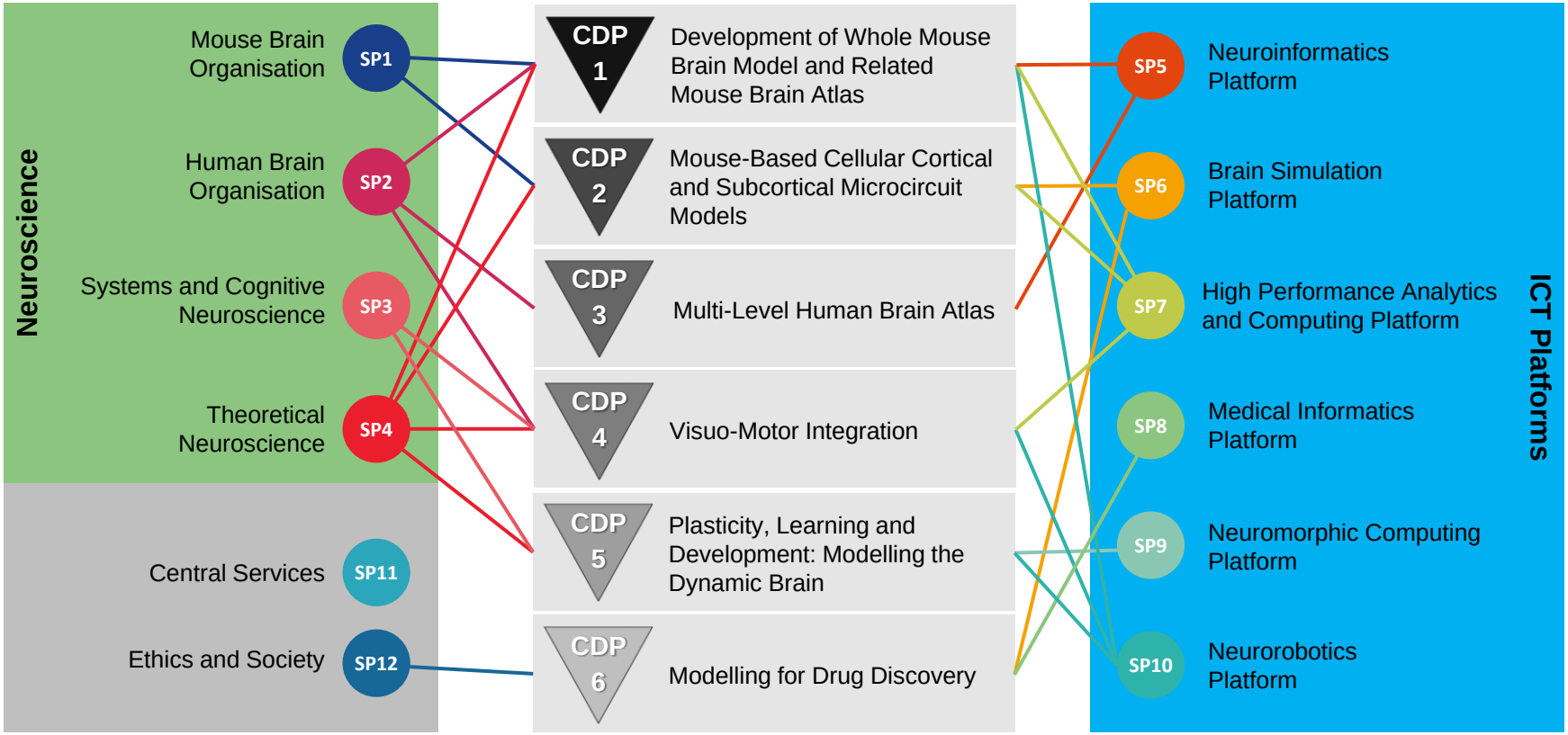


Accelerating Future Computing

Learn and derive from the brain to build the **supercomputers and robots of tomorrow**.



Breaking it down into Subprojects (SP) & Co-Design Projects (CDP)



SP1

HBP Partnering Projects

The FLAG-ERA Joint Transnational Call in 2015 (JTC2015) brought the first six Partnering Projects into the HBP.

Project	Description
CANON	The project investigates the canonical organisation of neocortical circuits for sensory integration.
ChampMouse	The project charts multi-areal visual perception in the mouse.
FIIND	This Partnering Project will develop a Ferret Interactive Integrated Neurodevelopment Atlas.
FUSIMICE	The project investigates ultrafast functional ultrasound (fUS) imaging for highly-resolved targeted mapping of functional connectivity in the awake mouse brain
MULTI-LATERAL	The project performs the multi-level integrative analysis of brain lateralisation for language.
SloW-Dyn	The project investigates slow wave dynamics: from experiments, analysis and models to rhythm restoration.

SP1

HBP Partnering Projects

SP1

CANON
Investigating the Canonical Organization of Neocortical Circuits for Sensory Integration
UvA (NL), INSERM (FR), IEM HAS (HU)

SP1

CHAMP Mouse
CHArting Multi-areal Visual Perception in the Mouse
KNAW (NL), KUL (BE), UPF (ES)

MULT-LATERAL
Multi-level Integrative Analysis of Brain Lateralization for Language
MPI (NL), BCBL (ES), UB (ES)

FIIND
Ferret Interactive Integrated Neurodevelopment Atlas
IP (FR), CEA (FR), RU (NL), McGill (CA)

SP1

FUSIMICE
Ultrafast Functional Ultrasound (fUS) Imaging for Highly-Resolved Targeted Mapping of Functional Connectivity in the Awake Mouse Brain
ESPCI (FR), INSERM (FR), IEM HAS (HU), UA (BE)

SloW-Dyn
Slow Wave Dynamics: from experiments, analysis and models to rhythm restoration
IDIBAPS (ES), IIT (IT), UPF (ES), Rythm SME (FR), CNRS (FR), Univ. Chicago (US)

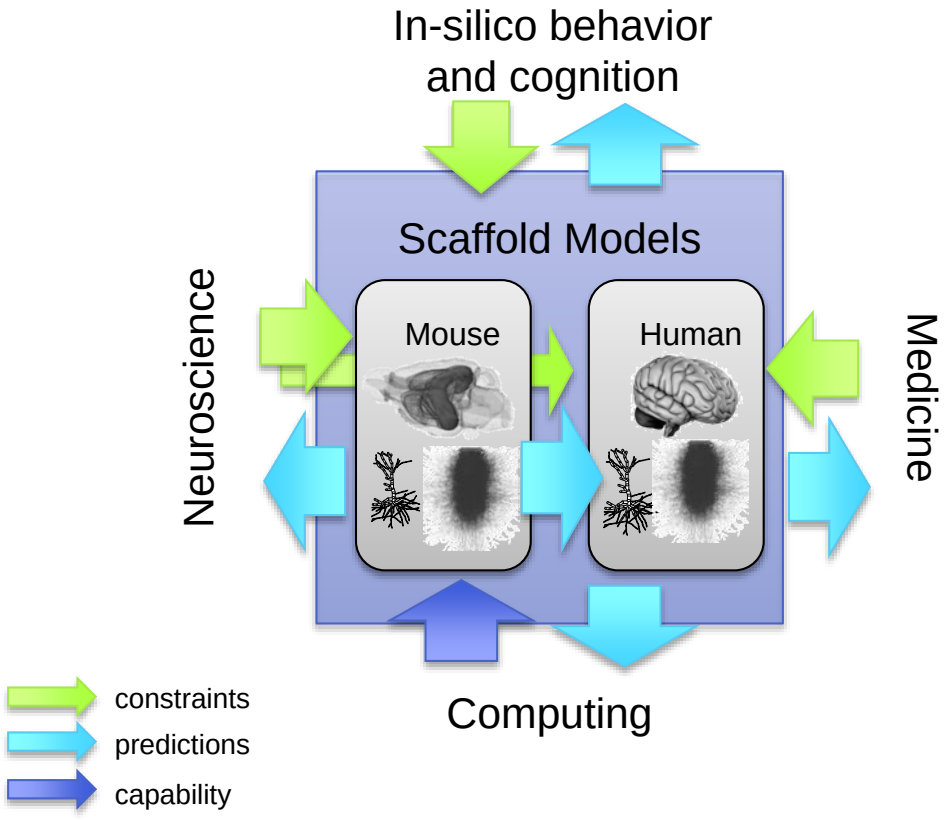
HBP Flagship Objectives (from SGA1)

1. Create & operate a European **Scientific Research Infrastructure**:
   a. For Brain Research
   b. For Cognitive Neuroscience, &
   c. For Other Brain-Inspired Sciences.
2. Gather, organise & disseminate data describing the brain & its diseases.
3. Simulate the brain.
4. Build multi-scale scaffold theory and models for the brain.
5. Develop brain-inspired computing, data analytics & robotics.
6. Ensure HBP work is undertaken responsibly & benefits society.

The HBP ICT Platforms

- **Collaborative research tools** for brain research and brain-inspired computing technologies
- Prototype hardware, software, databases, brain atlases, and programming interfaces
- **Continuous refinement** in close collaboration with end users
- Access via the **HBP Collaboratory: http://collab.humanbrainproject.eu/**

The HBP *Platform Universe* supports the science



Brain Simulation:
Collaborative integration of neuroscience data into multi-scale scaffold models and simulations of brain regions

Neurorobotics:
Testing brain models and simulations in dynamic virtual environments

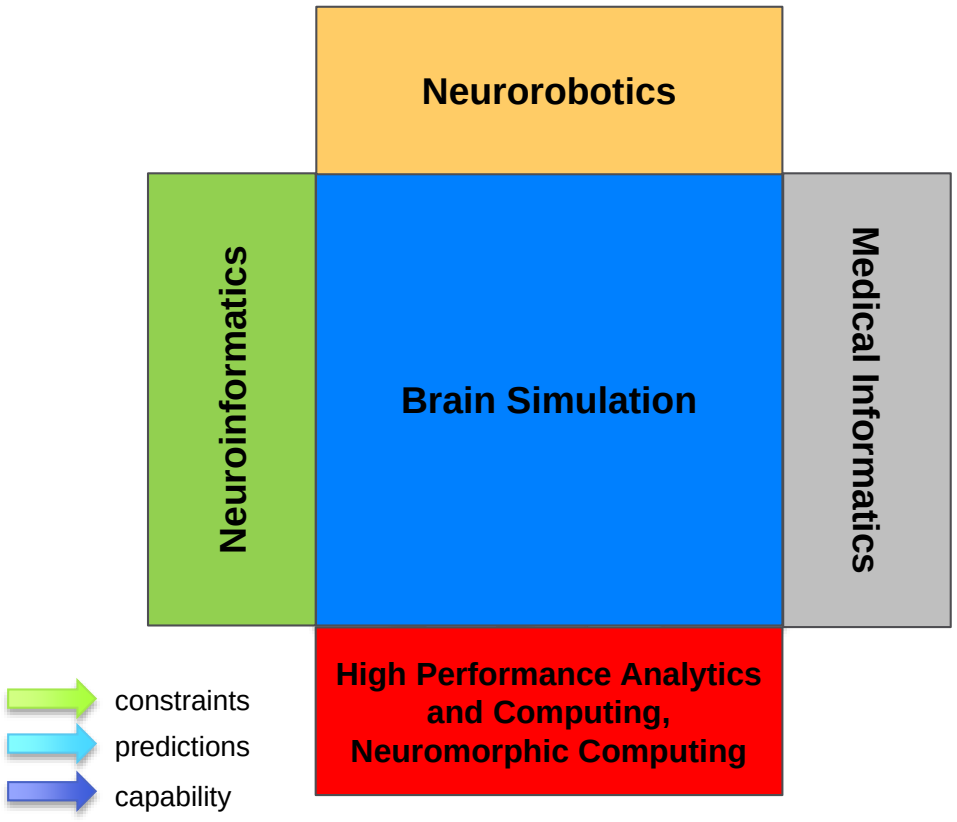
Neuroinformatics:
Organizing neuroscience data, mapping to brain atlases

Medical Informatics:
Bringing together information on brain diseases

Neuromorphic Computing:
ICT that mimics the functioning of the brain

High Performance Analytics and Computing:
Hardware and software to support the other Platforms

The HBP *Platform Universe* supports the science



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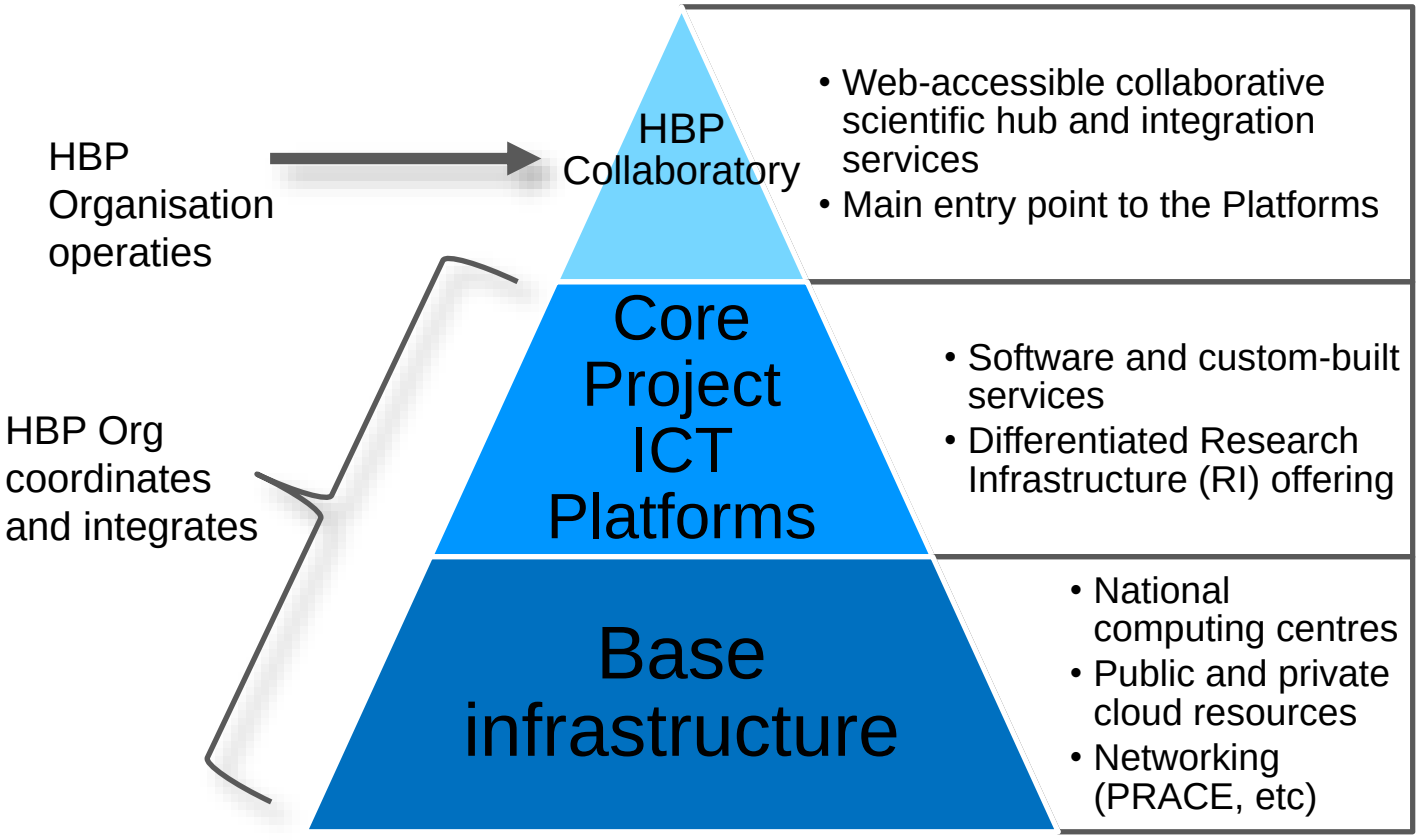
HBP Service-based Research Infrastructure (SRI)



HBP and Global Brain Initiatives

- HBP Delegation to this meeting (U.S. Brain Initiative Investigators' Meeting 2016) is a visible result of the high-level dialogue with U.S. Brain by both HBP Directors and the EC
- Kavli Foundation / GE Health "Brain Trust" meeting in La Jolla: U.S. and HBP taking leadership in bringing the Global Brain Initiatives together as an Alliance.
- Important meetings in Baltimore and at Rockefeller University in NY in conjunction with the U.N. General assembly leading up to global cooperation
- Special issue of Neuron devoted to "Global Neuroscience" – presents all the initiatives

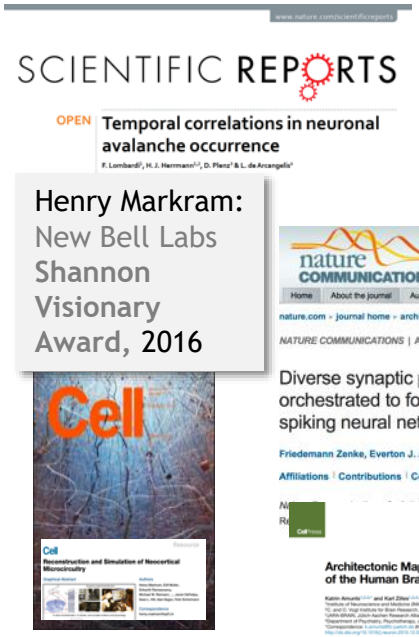
HBP Training and Mobility Grant

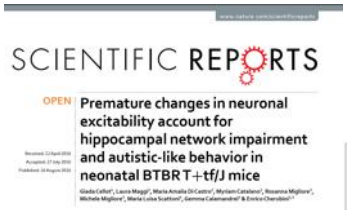
- Available to HBP PhD students, Postdocs, and selected researchers (e.g. guest professors) from HBP partner institutions
- Enables them to work / collaborate locally with a team or lab financed by US BRAIN
- Grant covers travel and living cost for 2-3 months, up to a maximum of EUR 5000.
- Main criteria for award are demonstrated scientific excellence, mutual benefit for HBP/USBRAIN, shows concrete research or infrastructure project, has approval of home and host lab/institute
- Grant mirrors US grants for US persons wishing to work at HBP member institutions with similar conditions.

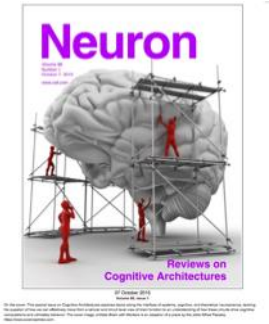
Scientific Achievements

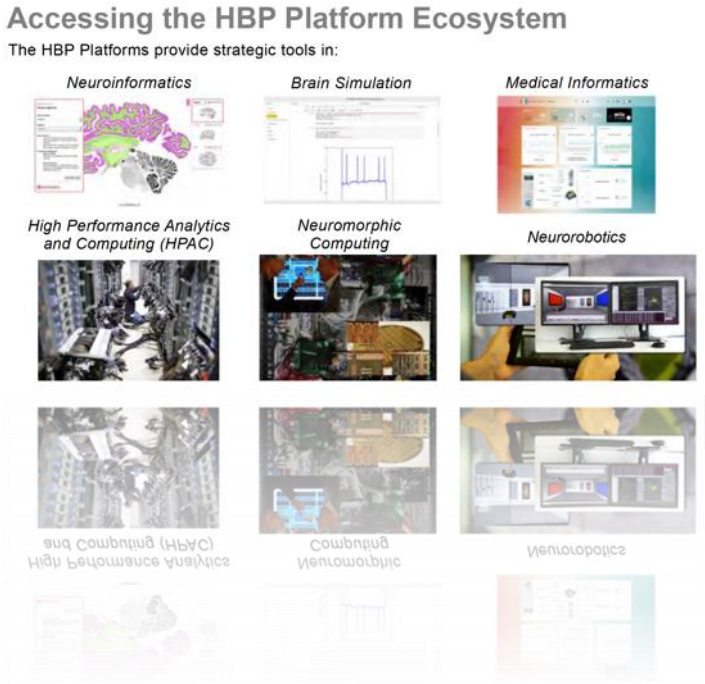
> 275 publications in scientific journals up to now

Platform Release March 30, 2016









Henry Markram: New Bell Labs Shannon Visionary Award, 2016

Jean-Pierre Changeux: Olav Thon Award, 2016

SP1

Co-funded by
the European Union

Human Brain Project

SP1 – Mouse Brain organization

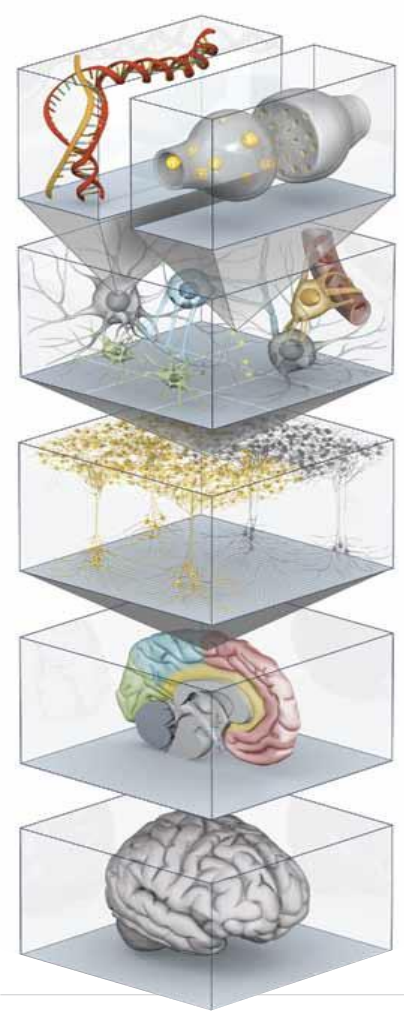
Subproject Leader: Javier DeFelipe

SP1 - Mouse Brain organization

The objective of SP1 is to generate

- neuroscientific concepts
- Knowledge
- experimental datasets and tools

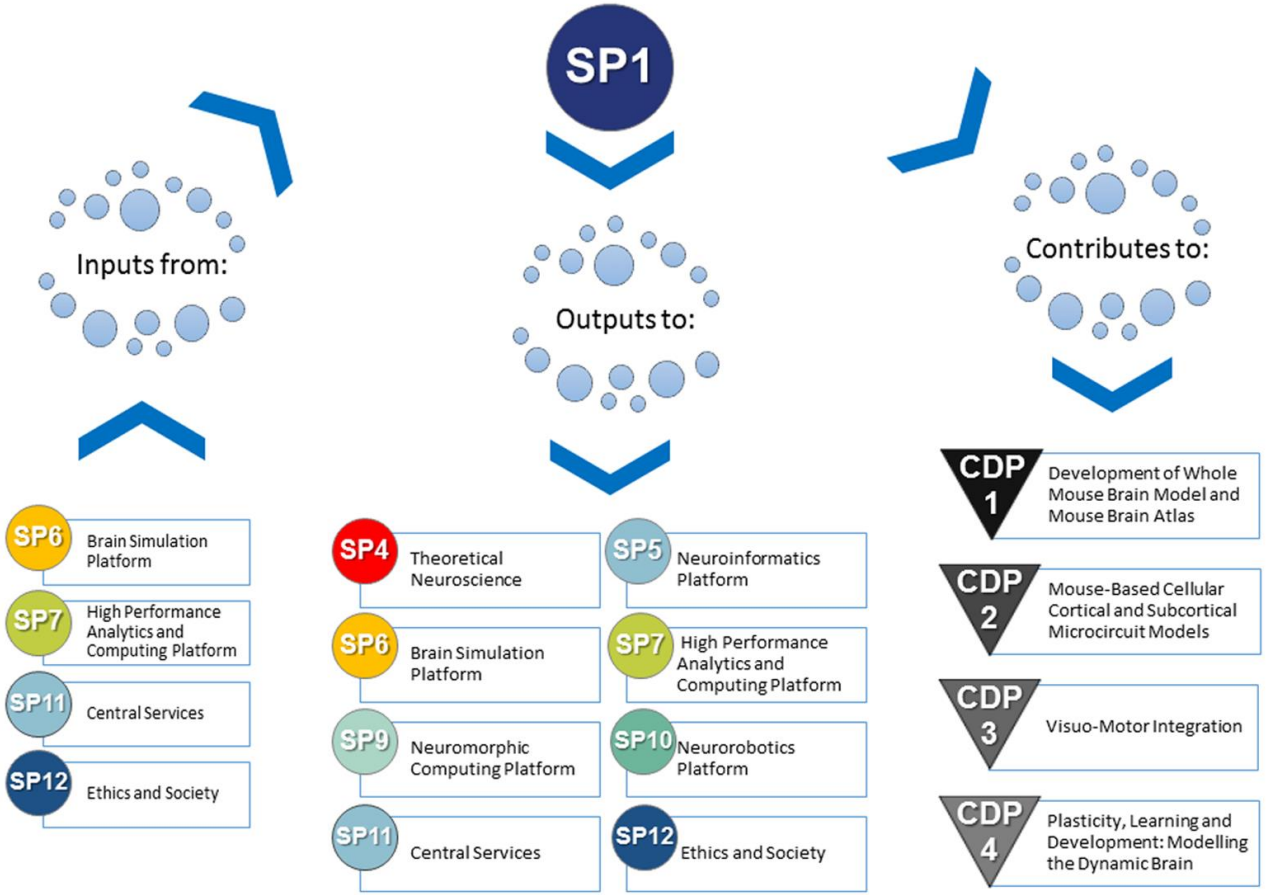
which will be used to build models for the simulation of the brain



An important role for SP1 is to provide data and knowledge to support activities undertaken by other SPs.

Mouse Brain Organization

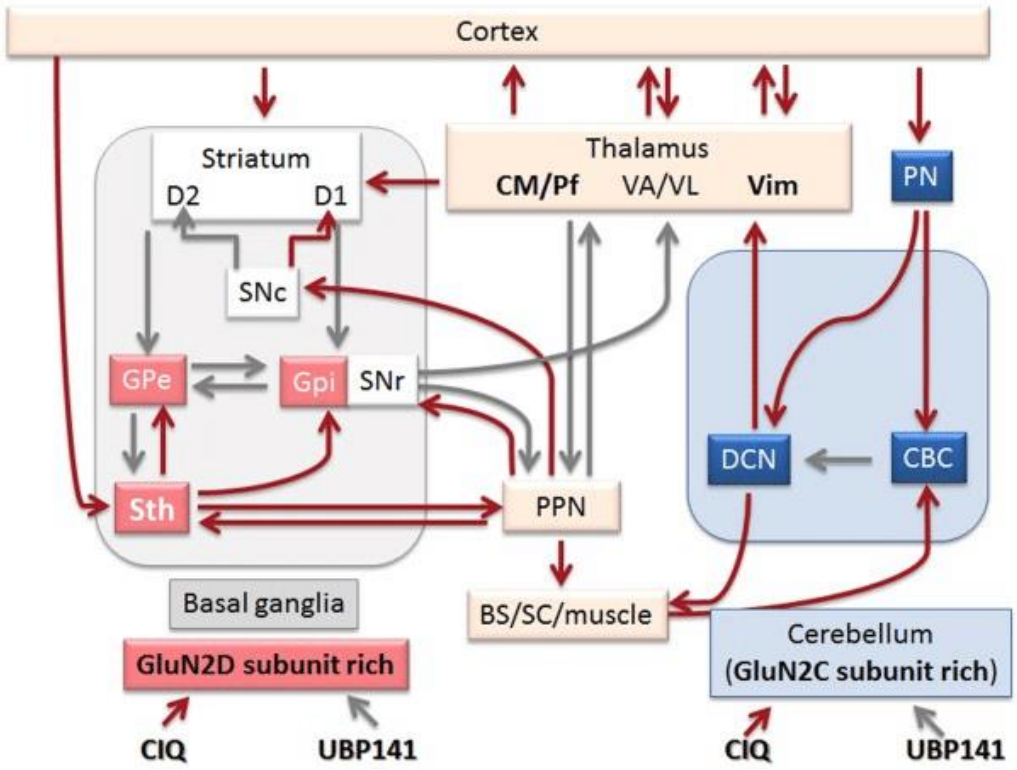
SP1 Interrelations



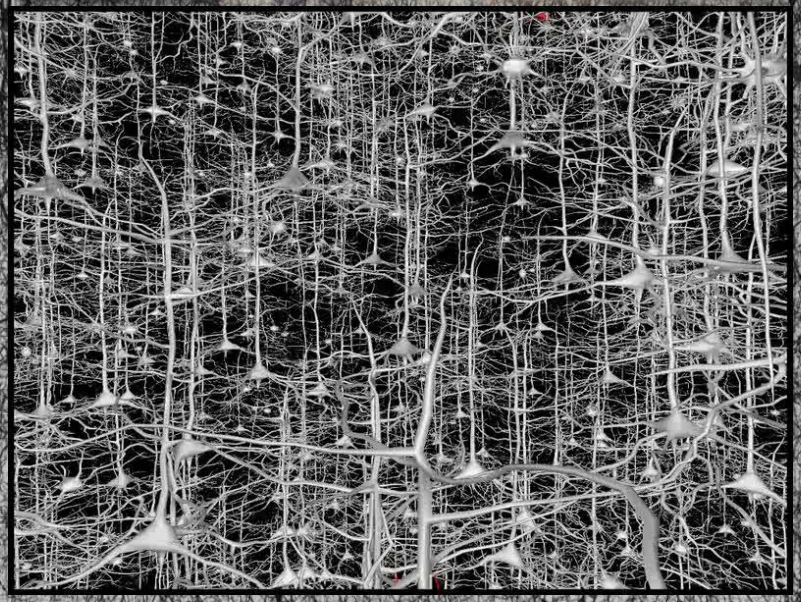
Mouse Brain Organization

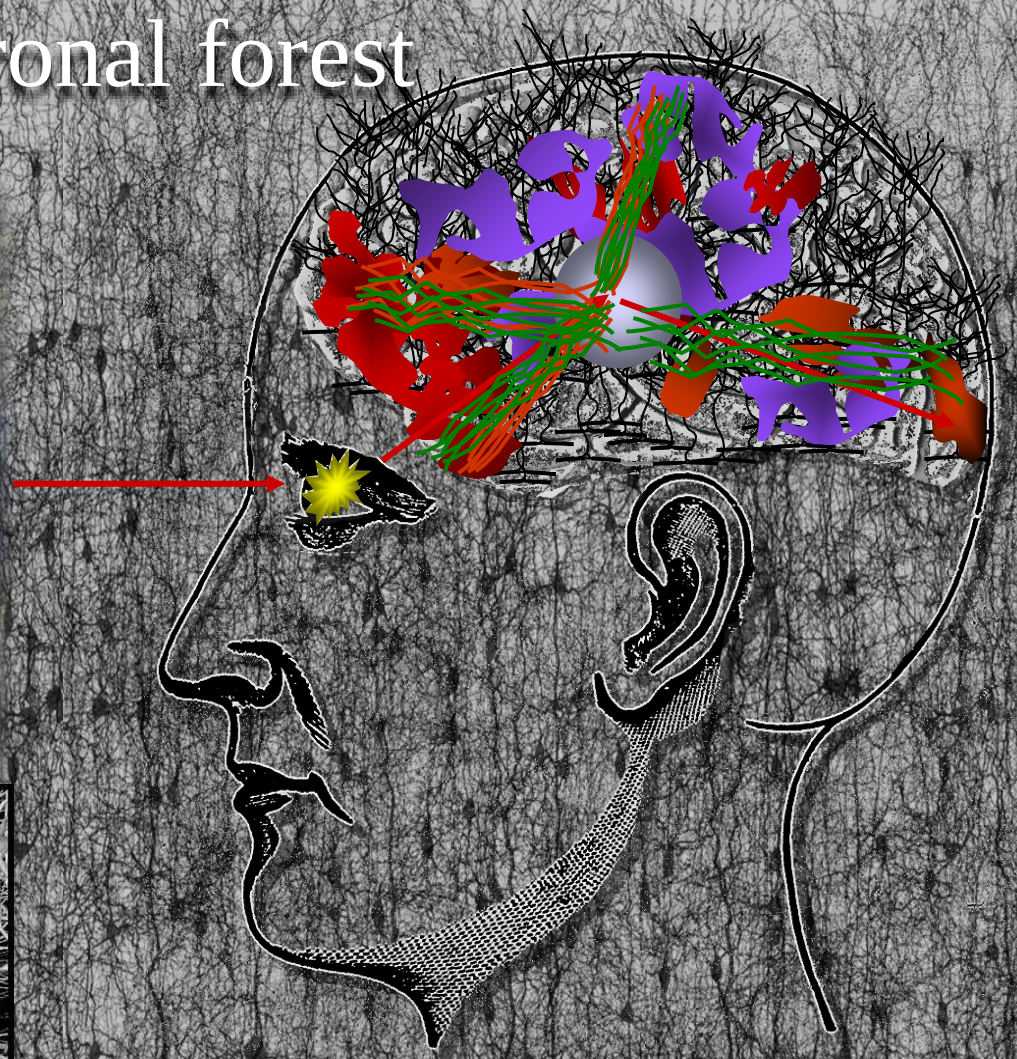
SP1 is currently focused on four major brain circuits to examine the molecular, genetic and anatomical patterns separately in particular regions:

- neocortex
- hippocampus
- basal ganglia
- cerebellum



Neuronal forest





How neuronal circuits contribute to the functional organization of the brain, giving rise to cognition and behavior?

One of the first steps is to define its detailed structural design and to map its connection matrix

Mouse Brain Organization

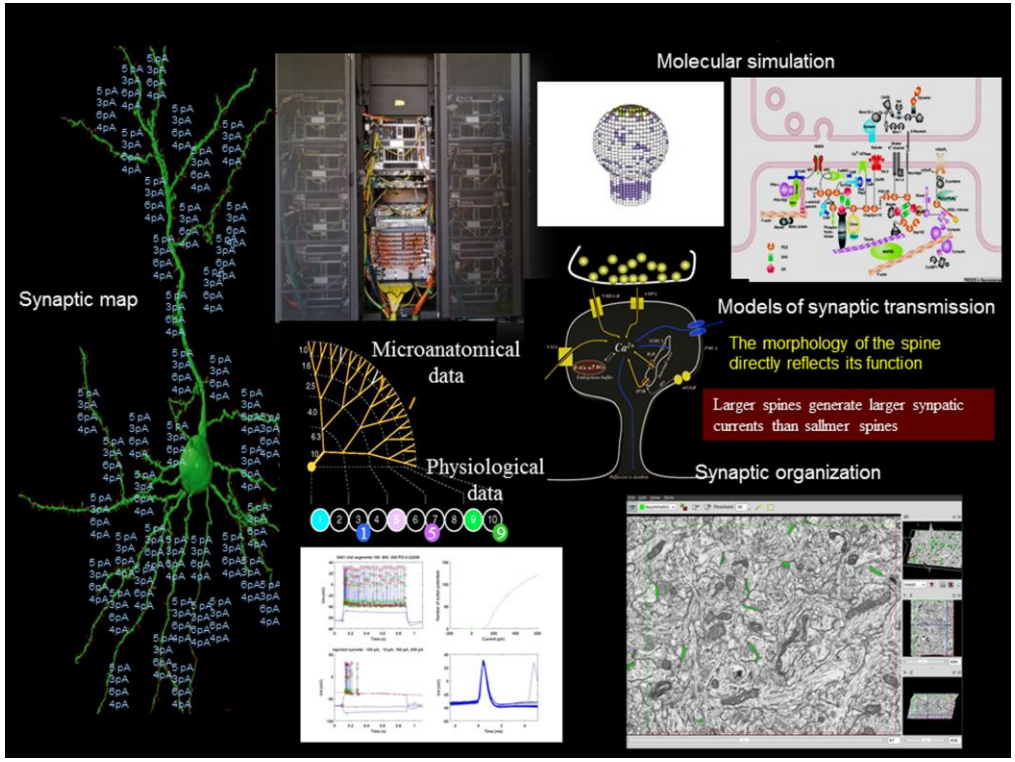
A major questions in neuroscience is what can be done with the data and how can it be interpreted.

"We are drowning in a sea of data and starving for knowledge. The biological sciences have exploded, largely through our unprecedented power to accumulate descriptive facts…. We need to turn data into knowledge and we need a framework to do it.

Sydney Brenner, Nobel lecture "Nature's gift to Science", 2002

It seems that the most appropriate approach to make neuroanatomical studies more significant is to integrate this neuroanatomical information with genetic, molecular and physiological data. This integration would allow the generation of models that present the data in a form that can be used to reason, make predictions and suggest new hypotheses to discover new aspects of the structural and functional organization of the brain.

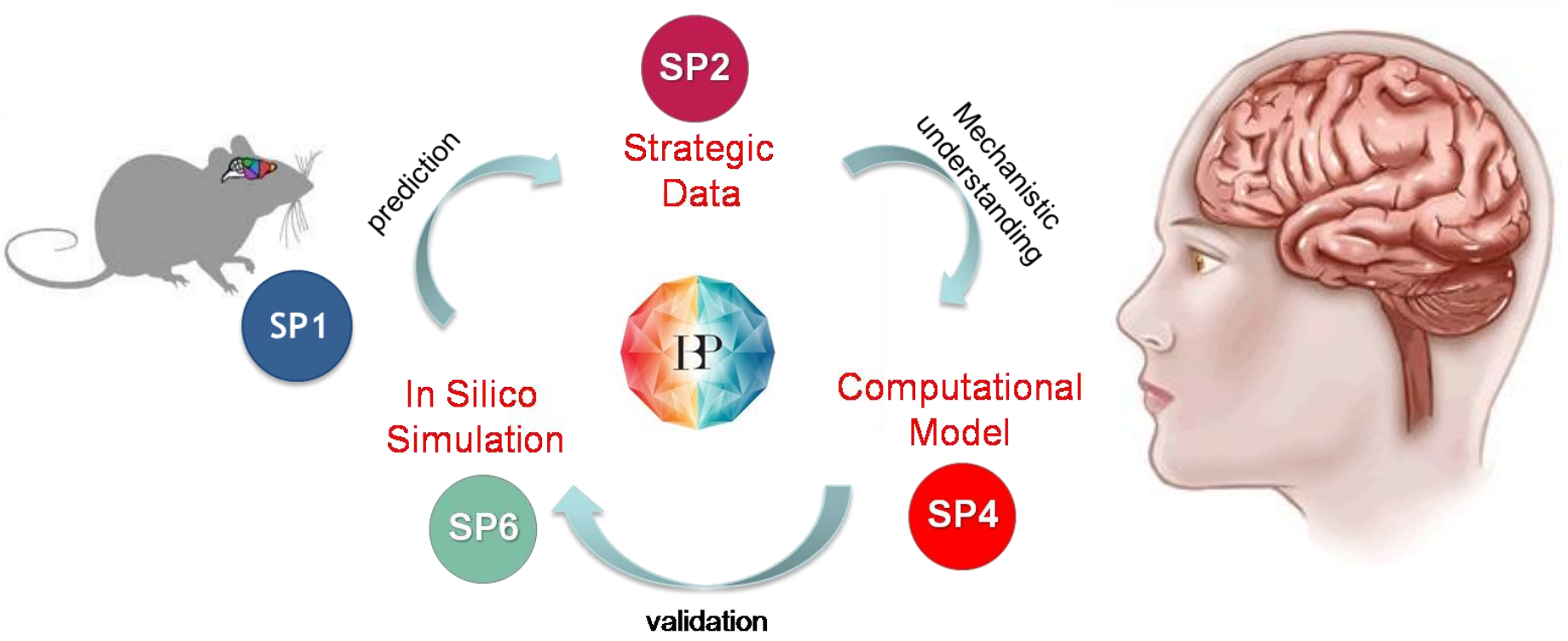
Examples of Data Integration and Simulation



SP1

Mouse Brain Organization

Understanding neuronal circuits in the human brain



SP1

Mouse Brain Organization

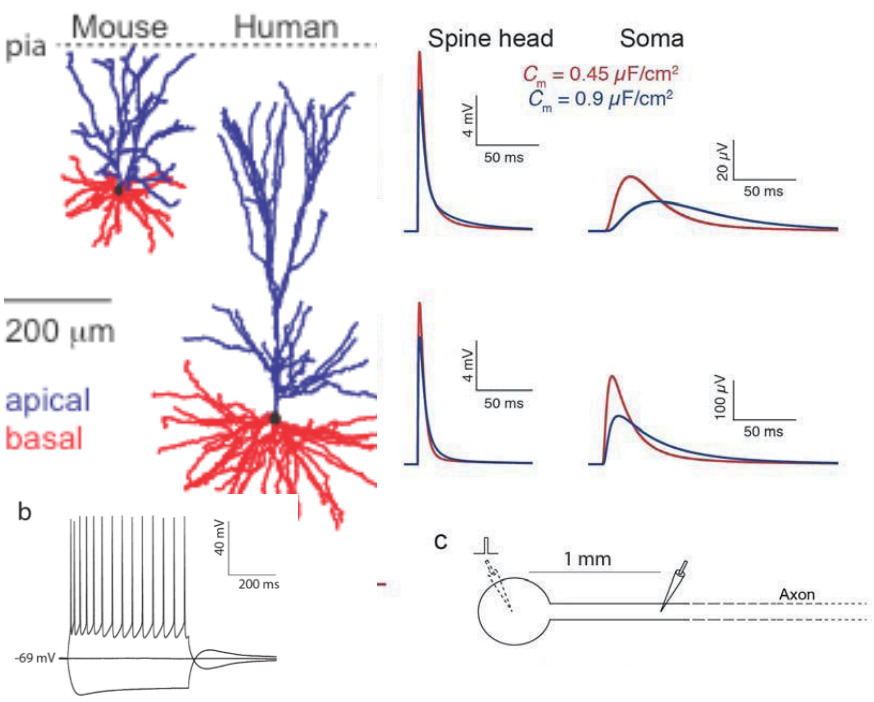
Unique Membrane Properties and Enhanced Signal Processing in Human Neocortical Neurons

This study focuses on layer 2/3 pyramidal cells from human temporal cortex (HL2/3 PCs) and provides, for the first time, a comprehensive biologically based modeling view on human neurons, including their passive and (somatic and dendritic) active properties. This study was made possible through a tight link between three diverse groups:

- (1) Anatomists working on the fine structure (including that of dendritic spines) of human cortical neurons from postmortem preparation (Javier DeFelipe and his tean in Madrid, Cajal Blue Brain Project). SP1
- (2) Two groups from Amsterdam (Christiaan de Kock and Huibert Mansvelder) that reconstruct in 3D human pyramidal cells and physiologically characterize these cells *in vitro* from living human neocortical tissue obtained through brain surgery. SP2
- (3) Theoretical team (from Jerusalem, Idan Segev and Guy Eyal) that integrated the above anatomical and physiological data to build (and learn from) the first-ever realistic model of any human neuron. SP4

Eyal G, Verhoog MB, Testa-Silva G, Deitcher Y, Lodder JC, Benavides-Piccione R, Morales J, DeFelipe J, de Kock CP, Mansvelder HD, Segev I (2016) Unique membrane properties and enhanced signal processing in human neocortical neurons. Elife. 2016 Oct 6;5. pii: e16553. doi: 10.7554/eLife.16553.

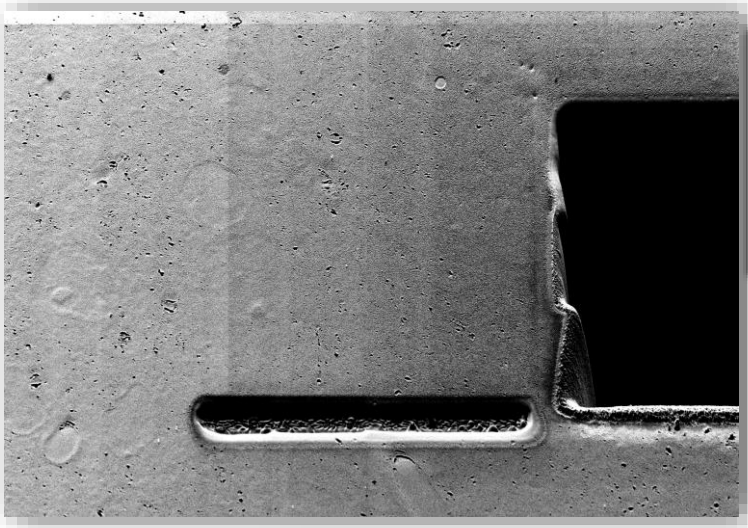
Cross species comparisons of cellular morphology and physiology



Co-funded by the European Union

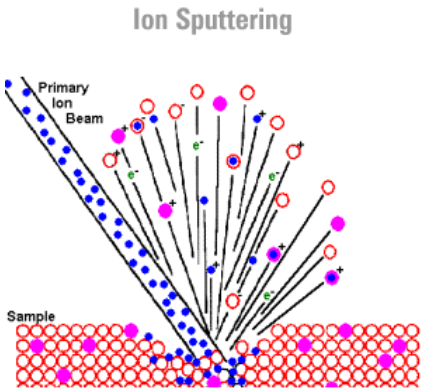
SP1

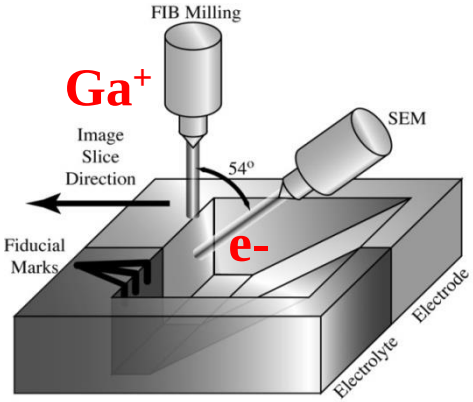
FIB/SEM technology

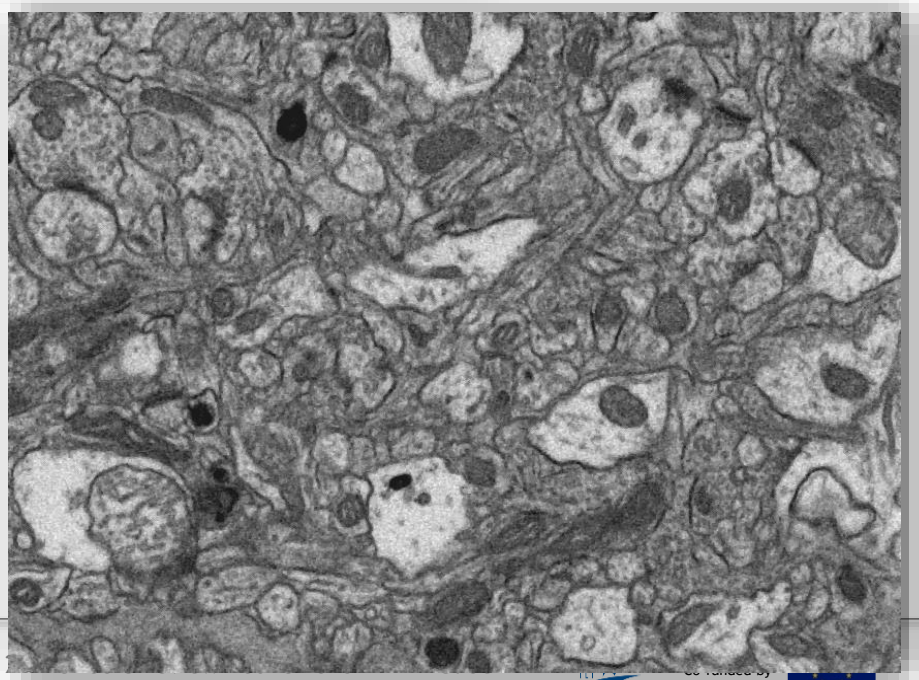


Automated electron microscopy techniques represent an important advance in the study of the synaptome.

This instrument combines a high resolution field emission scanning electron microscope (SEM) column with a focused gallium ion beam (FIB) which permits material to be removed from the sample surface on a nanometer scale.

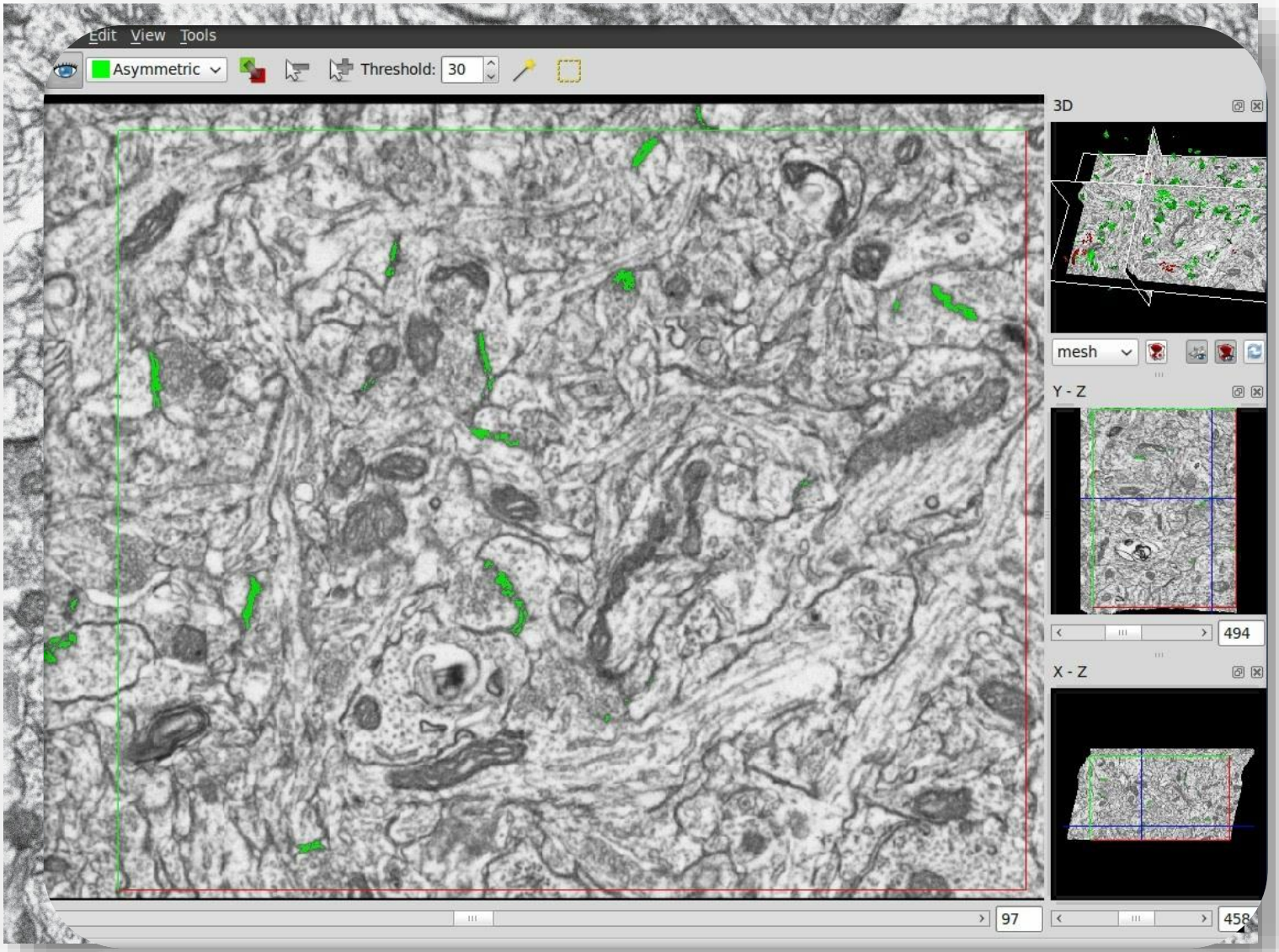






SP1

Segmentation of synaptic densities with Espina



Morales J, Alonso-Nanclares L, Rodríguez J-R, DeFelipe J, Rodríguez Á and Merchán-Pérez Á (2011) ESPINA: a tool for the automated segmenta-tion and counting of synapses in large stacks of electron microscopy images. *Front. Neuroanat. 5:18*