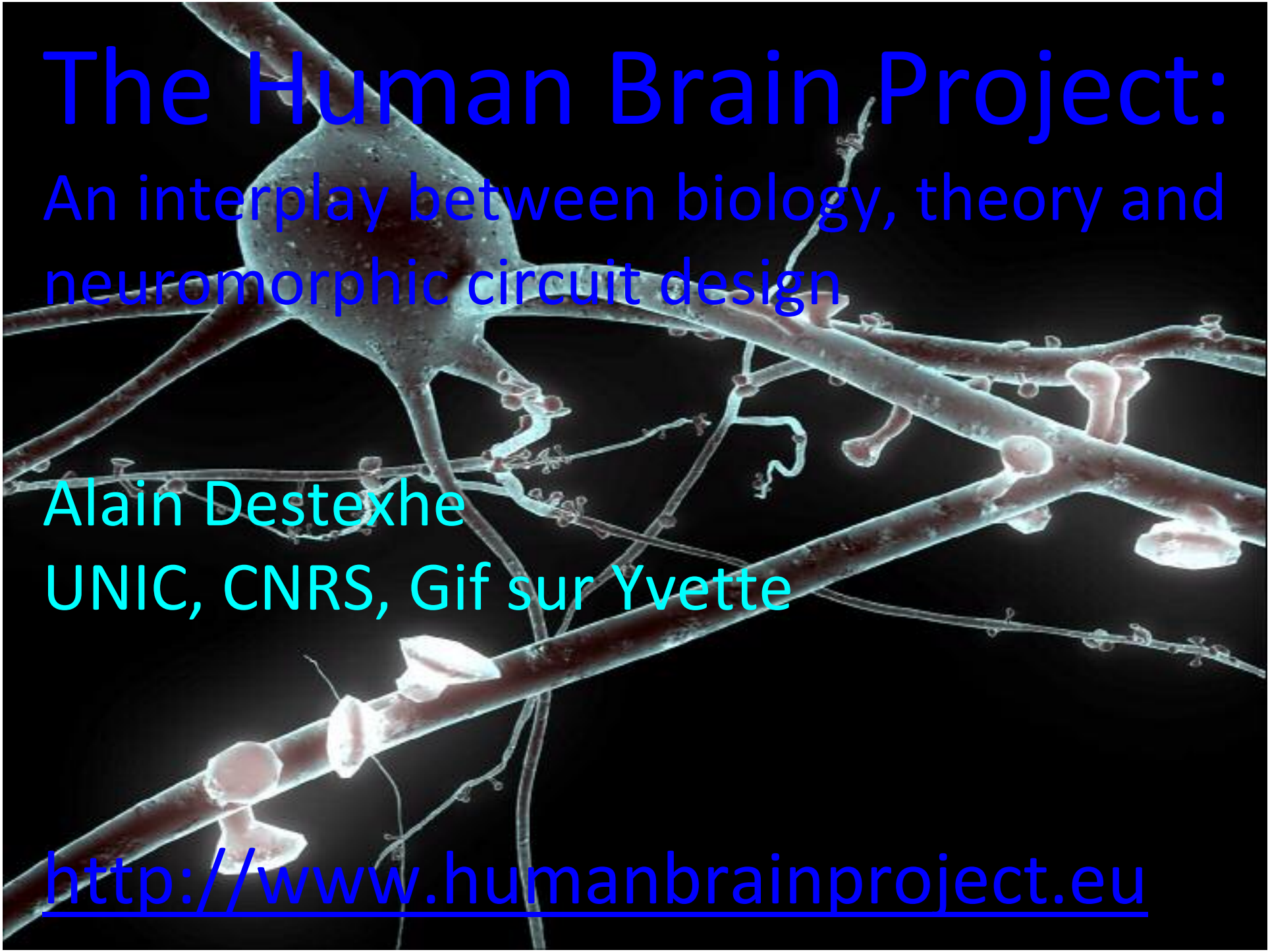


The Human Brain Project:

An interplay between biology, theory and neuromorphic circuit design

Alain Destexhe
UNIC, CNRS, Gif sur Yvette

http://www.humanbrainproject.eu

FET Flagships

- Large-scale, science-driven, visionary research initiatives
- Unifying goal
- Leading to : Technological innovation
  economic exploitation
  benefits for society

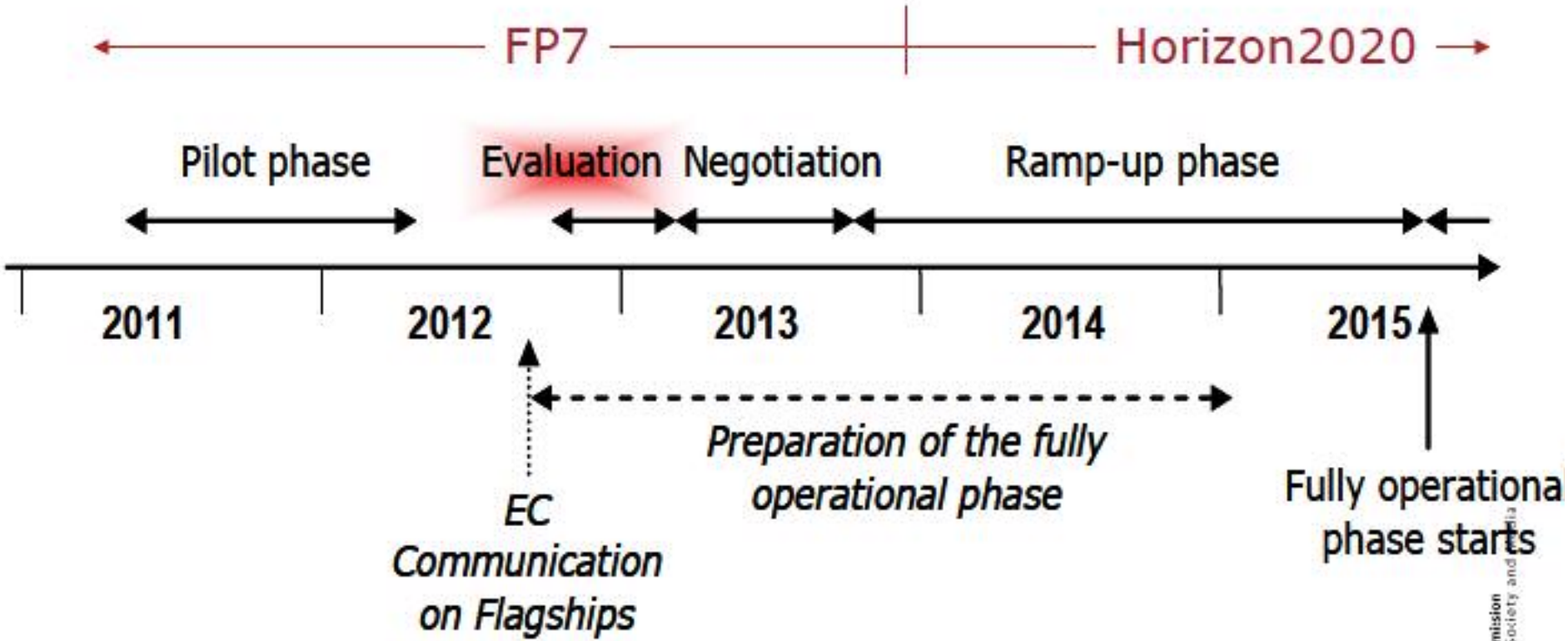
Duration : 10 Years
Budget : up to 100 MEuro per year

Federated effort of European research community and institutions, national and regional funding agencies, industry, global partners

FET FLAGSHIPS

FET Flagships
Timeline

FET Flagships timeline



6 Approved Coordination Actions (Pilot Projects) May 2011 – May 2012

FuturICT: *The FuturICT Knowledge Accelerator and Crisis-Relief System: Unleashing the Power of Information for a Sustainable Future*

Graphene: *Graphene Science and technology for ICT and beyond*

Guardian Angels: *Guardian Angels for a Smarter Planet*

HBP: *The Human Brain Project*

ITFoM: *The IT Future of Medicine*

RoboCom: *Coordination Action for the Design and Description of the FET Flagship Candidate Robot Companions for Citizens*

FET FLAGSHIPS

2 Approved Flagship Projects
February 2013

Graphene: *Graphene Science and technology for ICT and beyond*

HBP: *The Human Brain Project*

HBP

The Human Brain Project

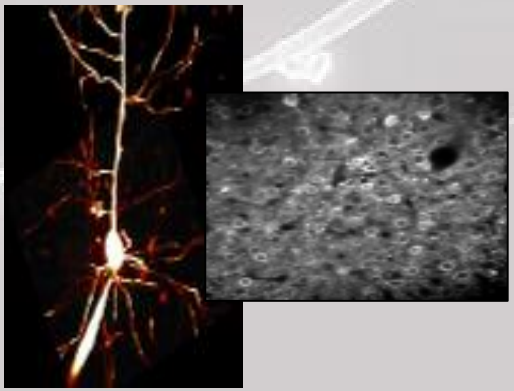
HBP in a nutshell

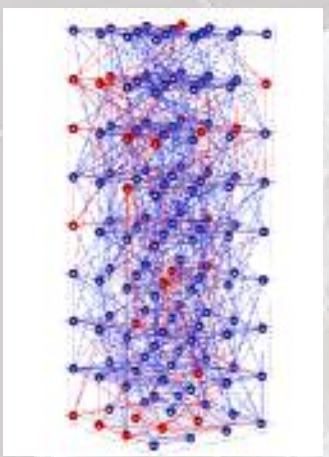
-to integrate neuroscience and clinical data from around the world into unifying computer models of the human brain
-to simulate the behavior of these models
-to develop applications for medicine and future computing

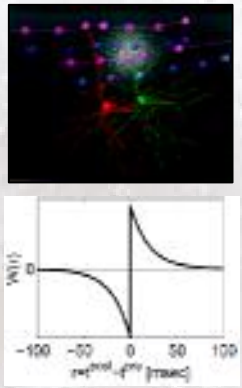
Currently partner groups from 22 countries, including all major EU member states as well as Switzerland, the USA, Japan and China. When fully operational, a science and engineering workforce of approximately 200 laboratories

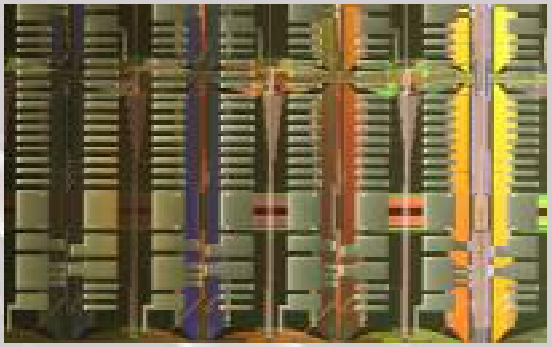
Biologie-Computation-Hardware

Comme des projets précédents tels que FACETS ou BRAINSCALES, un des objectifs du Human Brain Project est de comprendre la fonction et l'interaction entre les différentes échelles spatiales et temporelles du traitement d'information cérébrale, sur base de l'experimentation *in vivo* et de l'analyse computationnelle. Les principes théoriques génériques sont extraits et formalisés sous forme mathématique, pour ensuite les intégrer sur des circuits neuromorphiques.









Expérimentation Biologique

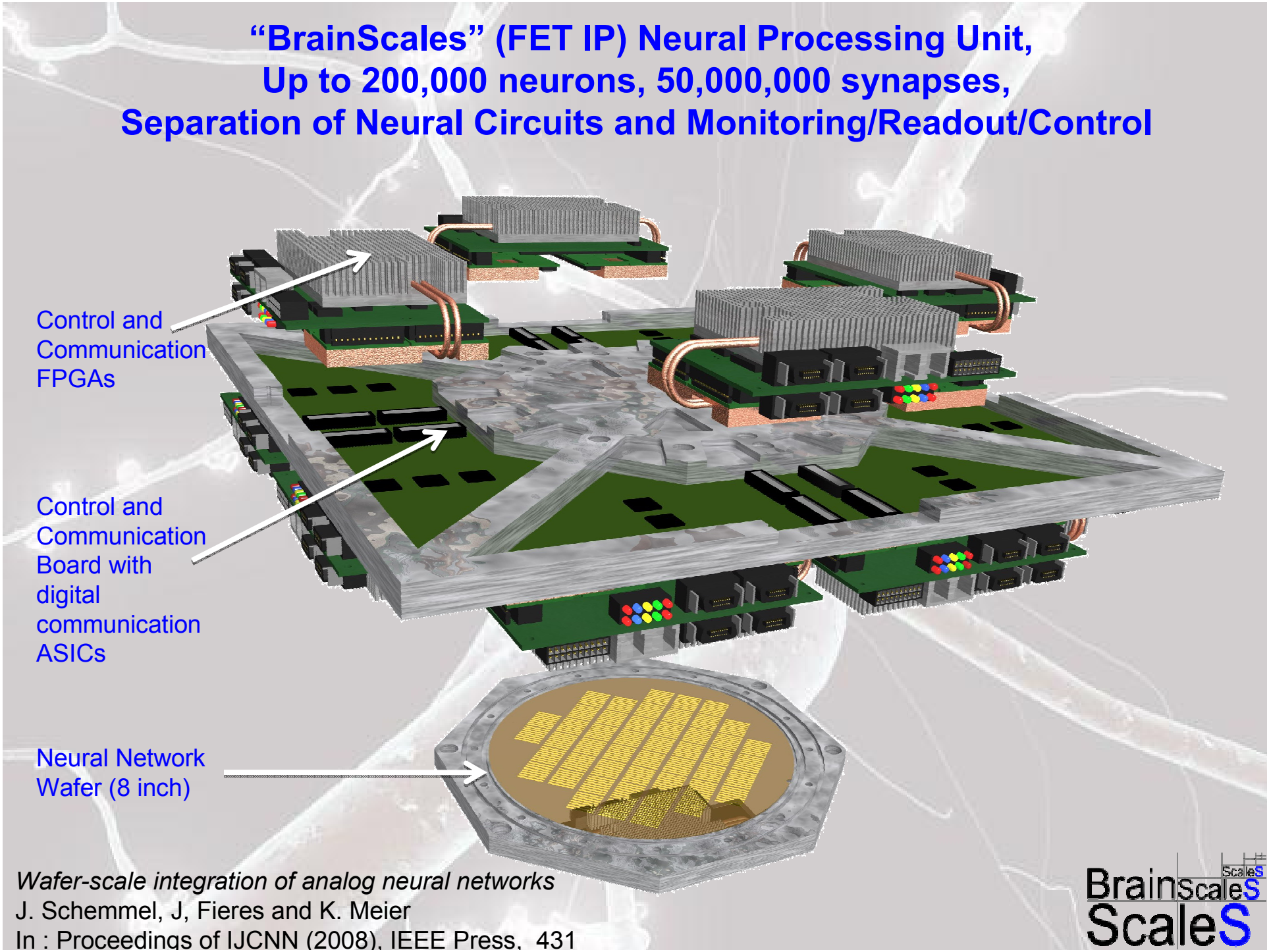
Modèles théoriques
Analyse mathématique
Simulation numérique

Circuits Neuromorphiques

FACETS

BrainScaleS
ScaleS

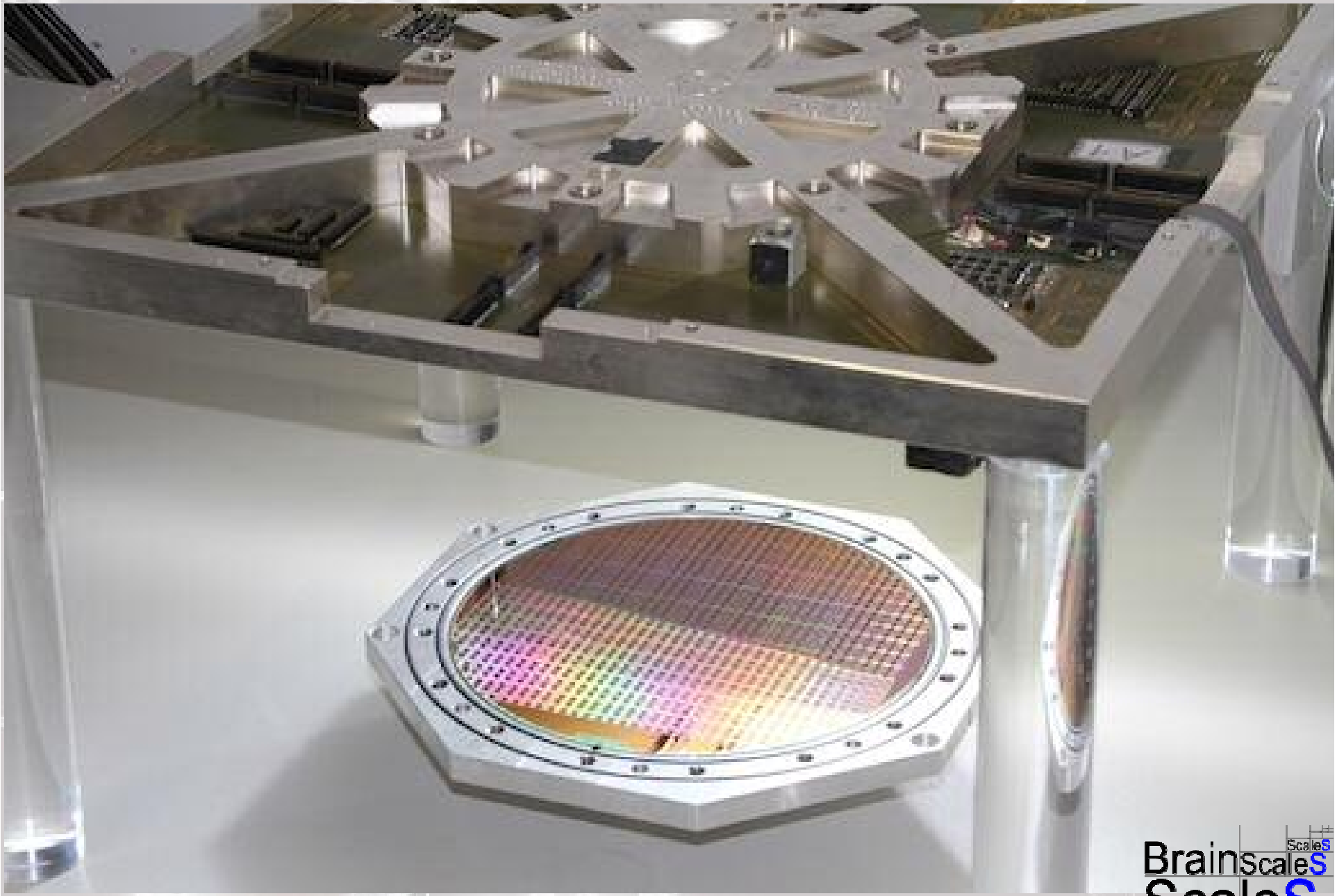
"BrainScales" (FET IP) Neural Processing Unit, Up to 200,000 neurons, 50,000,000 synapses, Separation of Neural Circuits and Monitoring/Readout/Control



Wafer-scale integration of analog neural networks
J. Schemmel, J, Fieres and K. Meier
In : Proceedings of IJCNN (2008), IEEE Press, 431

BrainScaleS

“BrainScales” (FET IP) Neural Processing Unit



8 Research Challenges of HBP

- From the basic constituents of the brain to behavior and cognition
- The neural code : How the brain represents information
- Foundations of consciousness
- The uniqueness of the human brain
- Simulation and prediction of diseases and therapies
- Beyond Turing : Implementing brain inspired computing paradigms
- Brain inspired computing paradigms outside biology
- High performance computing as a scientific instrument

Structure of the HBP

3 RESEARCH AREAS	Brain Simulation – Brain Disease – Future Computing
12 PILLARS	Provide scientific excellence in scientific key disciplines
7 FACILITIES	Provide capabilities through European HBP Research Labs
CHALLENGES	Perform interdisciplinary, curiosity driven and applied research using pillar excellence and facility capabilities

Implication of France

3 Pillar Directors:

Cognitive neuroscience	**Stanislas Dehaene** (CEA, NeuroSpin)
Theoretical neuroscience	**Alain Destexhe** (CNRS)
Ethics	**Jean-Pierre Changeux** (Pasteur)

Many Core Partners:

INRIA (Faugeras, Thirion), CEA (NeuroSpin, LETI), CNRS (Destexhe, Brunel, Frégnac, Renaud, ...), INSERM (Brice, Jirsa), ENS (Triller), Pasteur, UPMC, ...

Pillars : Future Computing

what will they provide ? – a few selected items

High Performance Computing

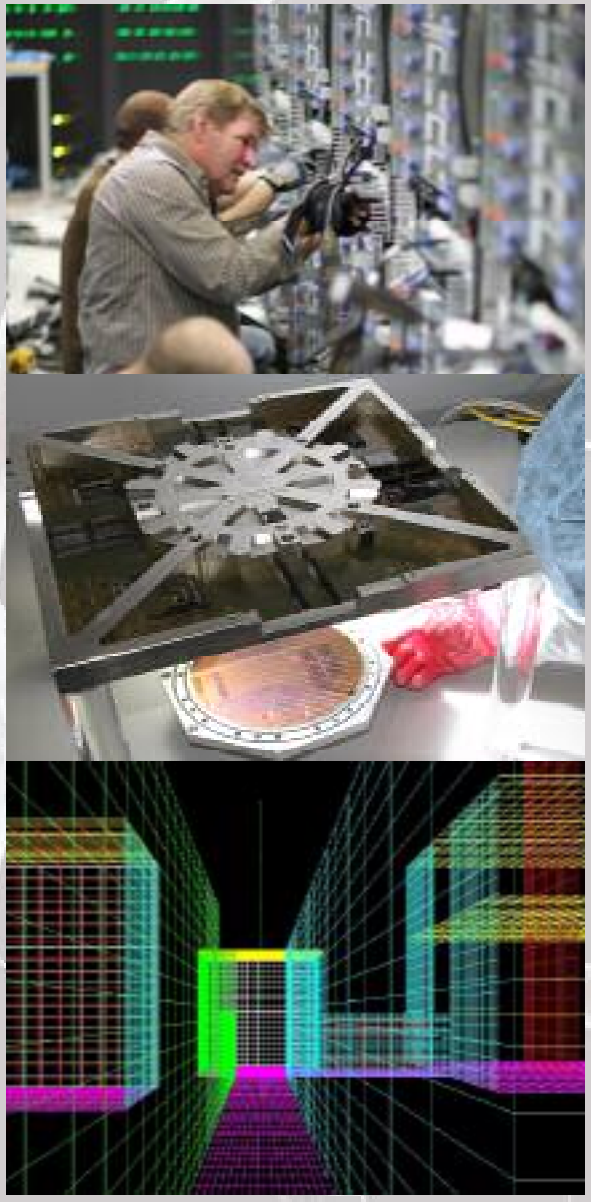
- Interactive, visual. Exascale supercomputing
- Massive distributed volumes of heterogeneous data
- Convergence with neuromorphic technology

Neuromorphic Computing

- First large-scale neuromorphic systems superior to HPC
- Non-von Neumann (Multicore) + non-Turing (Neuromorph)
- Technology integration (3D, non-CMOS backends)

Neurorobotics

- Virtual robots with two-way, closed loop interfaces
- Link to brain models and neuromorphic systems
- Physical prototypes and applications



European HBP Facilities in the Future Computing Research Area

High Performance Computing Platform (Jülich, major installations also in Barcelona, EPFL, CSCS)

Neuromorphic Computing Platform (Heidelberg)

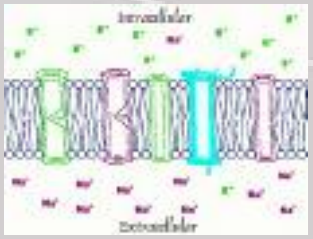
Neurorobotics Platform (Munich)

European Institute for Theoretical Neuroscience **(Paris)**

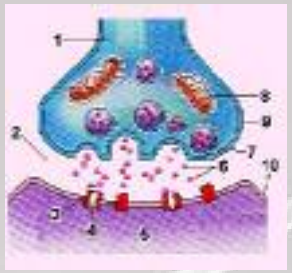
HBP Facilities and Institutes are seeds for a sustained impact in the European research landscape in research, training and teaching

HBP Theoretical Neuroscience

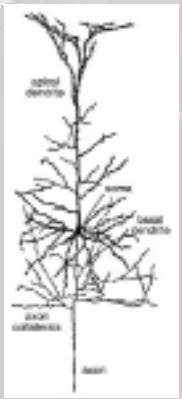
Echelles spatiales du cerveau



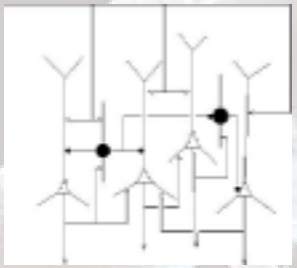
Moléculaire (~10 nm)



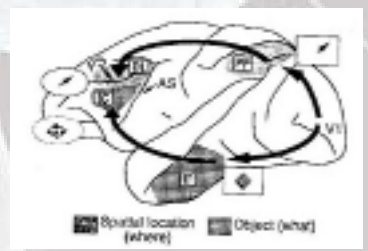
Sub-cellulaire (100 nm – 1 µm)



Neurone (10 µm – 1 mm)



Circuits locaux (100 µm – 1 mm)



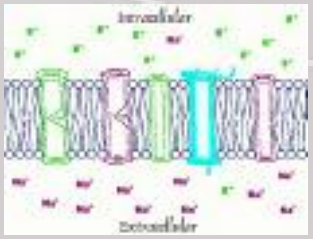
Aire corticale (~1 cm)

Cerveau (~10 cm)

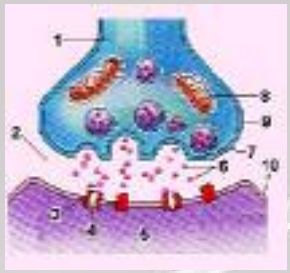
HBP Theoretical Neuroscience

Echelles spatiales du cerveau

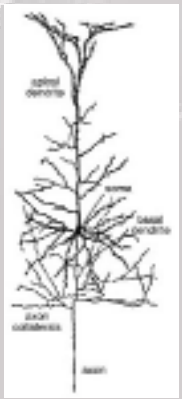
+ Techniques expérimentales



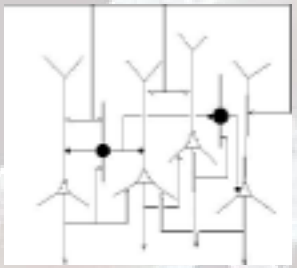
Moléculaire (~10 nm)
Biochimie, Bio Mol.



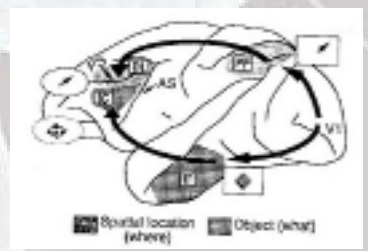
Sub-cellulaire (100 nm – 1 µm)
Microscopie électronique



Neurone (10 µm – 1 mm)
Enregistrement intracellulaire, patch clamp



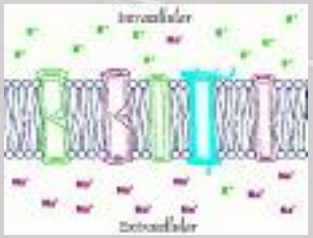
Circuits locaux (100 µm – 1 mm)
VSD, multi-électrode, 2-photon



Aire corticale (~1 cm)
VSD, fMRI

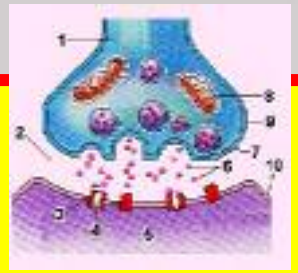
Cerveau
(~10 cm)
fMRI, EEG, MEG

HBP Theoretical Neuroscience



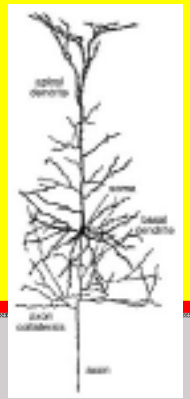
Moléculaire (~10 nm)
Biochimie, Bio Mol.

Echelles spatiales du cerveau
+ Techniques expérimentales

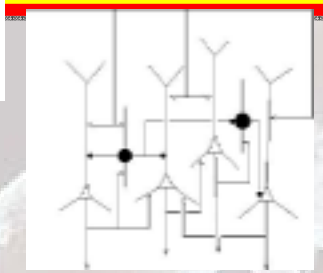


Sub-cellulaire (100 nm – 1 µm)
Microscopie électronique

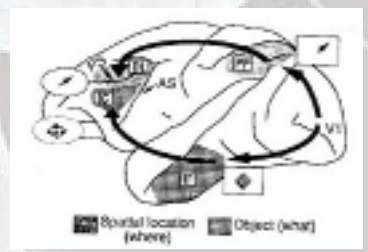
BlueBrain



Neurone (10 µm – 1 mm)
Enregistrement intracellulaire, patch clamp



Circuits locaux (100 µm – 1 mm)
VSD, multi-électrode, 2-photon

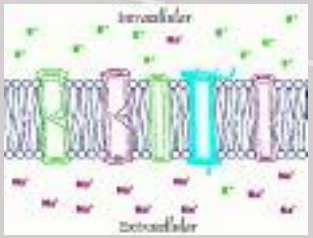


Aire corticale (~1 cm)
VSD, fMRI

Cerveau
(~10 cm)
fMRI, EEG, MEG

HBP Theoretical Neuroscience

Echelles spatiales du cerveau
+ Techniques expérimentales



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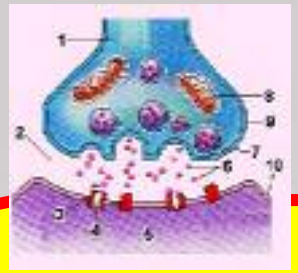
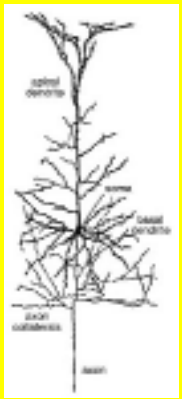
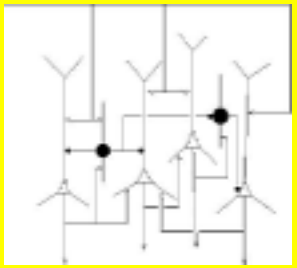


Sub-cellulaire (100 nm – 1 µm)
Microscopie électronique

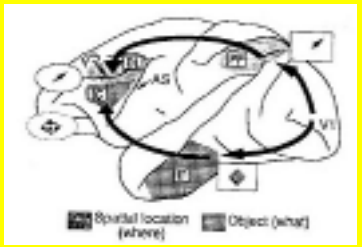
Human Brain Project



Neurone (10 µm – 1 mm)
Enregistrement intracellulaire, patch clamp



Circuits locaux (100 µm – 1 mm)
VSD, multi-électrode, 2-photon



Aire corticale (~1 cm)
VSD, fMRI

Cerveau
(~10 cm)
fMRI, EEG, MEG

HBP Theoretical Neuroscience

Pillar Goals

- Main Goal: extract mathematical concepts of brain-style computation that can guide the research in the Simulation and HPC fields and are portable to applications in neuromorphic engineering, neuroscience, and robotics.
- Sub goal 1: Bridge different levels of description, from detailed to abstract models, and different scales from single cells to large networks of neurons.
- Sub goal 2: Develop learning algorithms that can structure experimental data and simulations of synaptic plasticity for memory formation.
- Sub goal 3: Develop large-scale models of cognitive functions, such as spatial navigation, decision making, up to the mechanisms of sensory perception and consciousness.
- Sub goal 4: Investigate general principles of neural computation, which can be transferred to other disciplines beyond neuroscience.

HBP Theoretical Neuroscience

Open Calls

European flagships: new concept, open structure, new partners can join during the project

Competitive calls: Mechanism to involve new partners, consists of project grants representing 20% of the total HBP budget (in principle close to 200 Million Euros over 10 years). Competitive calls serve to augment the capacities of the HBP consortium. The scientific themes of the competitive calls are decided by the partners, who identify areas where an external contribution is necessary.

Open calls: A significant proportion of competitive calls will be "open" to any subject in relation to the research done in HBP. In this case, it is up to the external partner to decide and describe how this contribution is fitting with HBP.

Open calls in theoretical neuroscience: one of the justification of the European Institute for Theoretical Neuroscience is to involve new theoreticians in the project, to maintain this quickly-changing area very active (involve new theories etc), and this is supposed to happen through the open calls.

HBP Theoretical Neuroscience

L'Institut Européen des Neurosciences Théoriques (*European Institute for Theoretical Neuroscience*)

- 200 m2 en Région Parisienne (ENS? Descartes? Saclay?)
- 4 postdocs (contrat de 2 ans) présents en permanence
- Implication de la communauté théorique de Paris et Saclay
- Cycles de conférences et workshops avec invités extérieurs
- Programme de visiteurs jusqu'à 3 mois (avec stipend)
- « Competitive call » spécifique aux neurosciences théoriques

Le CNRS en est l'opérateur principal (via A Destexhe)

Capacités doublées en phase 2

HBP Theoretical Neuroscience

Participants

Nicolas Brunel
Neil Burgess (Theory and Cognitive)
Gustavo Deco
Alain Destexhe
Olivier Faugeras
Wulfram Gerstner
Victor Jirsa
Wolfgang Maass
Idan Segev (Theory and Simulation)
Walter Senn
Olaf Sporns
Misha Tsodyks (Theory and Cognitive)
Shimon Ullmann

+ Paris Theoretical Neuroscience community

+ DeepMind Technologies (London)