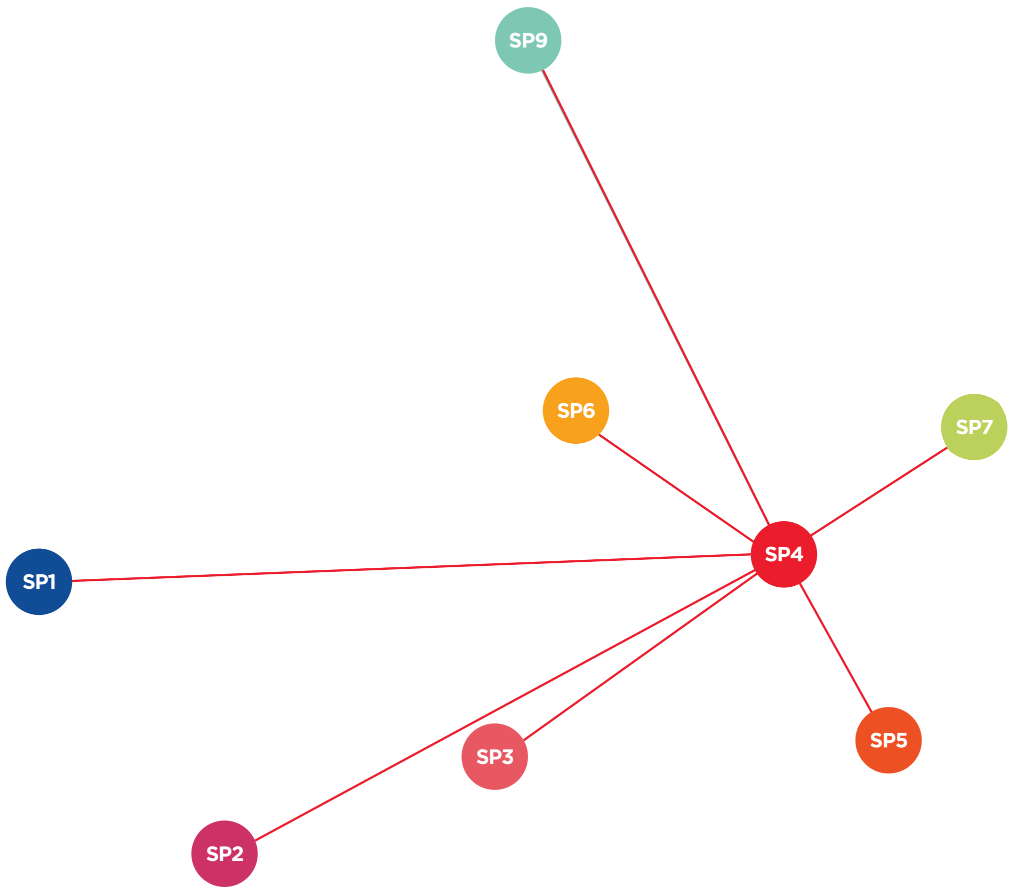
SP4

THEORETICAL NEUROSCIENCE

Human Brain Project



SP4 INTERACTS DIRECTLY WITH SEVERAL OTHER SUBPROJECTS

Subproject 1 SP1 Strategic Mouse Brain Data – **Subproject 2** SP2 Strategic Human Brain Data – **Subproject 3** SP3 Cognitive Architectures – **Subproject 4** SP4 Theoretical Neuroscience – **Subproject 5** SP5 Neuroinformatics Platform – **Subproject 6** SP6 Brain Simulation Platform – **Subproject 7** SP7 High Performance Computing Platform – **Subproject 8** SP8 Medical Informatics Platform – **Subproject 9** SP9 Neuromorphic Computing Platform – **Subproject 10** SP10 Neurorobotics Platform – **Subproject 11** SP11 Applications – **Subproject 12** SP12 Ethics and Society

SP4

THEORETICAL NEUROSCIENCE

The Human Brain Project (HBP) is a European Commission Future and Emerging Technologies Flagship that aims to achieve a multi-level, integrated understanding of brain structure and function through the development and use of information and communication technologies (ICT). These technologies will enable large-scale collaboration and data sharing, reconstruction of the brain at different biological scales, federated analysis of clinical data to map diseases of the brain, and the development of brain-inspired computing systems.

The HBP is working to achieve an integrated, multi-level understanding of brain structure and function through the development and use of information and communication technologies (ICT)

The HBP's ICT Platforms will allow neuroscientists, clinical researchers and information technology developers to perform diverse experiments and share knowledge, with a common goal of unlocking the most complex structure in the known universe. During the first two-and-a-half years (the Ramp-Up Phase), the HBP will collect strategic data, develop theoretical frameworks and perform the development work necessary to make the six ICT Platforms available for use by the scientific community in the Operational Phase. The HBP's ICT Platforms are:

- Neuroinformatics (a data repository, including brain atlases)
- Brain Simulation (building ICT models and simulations of brains and brain components)
- Medical Informatics (bringing together information on brain diseases)
- Neuromorphic Computing (ICT that mimics the functioning of the brain)
- Neurorobotics (testing brain models and simulations in virtual environments)
- A High Performance Computing Platform will support the other platforms

The HBP was launched in 2013 and brings together more than 100 academic and corporate Partners in more than 20 countries. HBP research is organised into twelve Subprojects (SP), each broken down into Work Packages (WP) and Tasks (T), with well-defined goals and milestones. Six Subprojects are building the ICT Platforms, while the other six are gathering data, clarifying theory and controlling ethical aspects. An additional Subproject manages and coordinates the HBP.

With an unprecedented cross-disciplinary scope, the HBP's goal is to catalyse a global collaborative effort to understand the human brain and its diseases and, ultimately, to emulate its computational capabilities.

Operational Objectives

Theoretical insights from mathematics can make a valuable contribution to many different areas of HBP research, from modelling of low-level biological processes, to the analysis of large-scale patterns of brain activity and the formalisation of new paradigms of computation. The HBP thus includes a cohesive programme of theoretical research addressing strategically selected themes essential to the goals of the Project: mathematical techniques to produce simplified models of complex brain structures and dynamics; rules linking learning and memory to synaptic plasticity; large-scale models creating a bridge between "high-level" behavioural and imaging data; and mathematical descriptions of neural computation at different levels of brain organisation. In addition to the plannable, cohesive theory programme implemented by the HBP Partners, brain theory also needs to explore unconventional ideas, which are most likely to come from outside the current HBP Consortium. To foster interaction with outside scientists, the HBP has established a European Institute for Theoretical Neuroscience (EITN), which works as an incubator for approaches that challenge traditional wisdom.

The main objectives of SP4 for the Ramp-Up Phase are to I) provide models and mathematical techniques to link different model types (from detailed to simplified); II) provide models of brain signals at different scales, from cellular to large-scale; III) provide models of synaptic plasticity, learning and memory; IV) provide models of several cognitive functions, such as perception-action, attention, working memory, as well as brain states such as wakefulness and sleep; V) extract general principles of neural computation that can guide the design and implementation of Neuromorphic Computing Systems; VI) establish a European Institute for Theoretical Neuroscience to involve the theoretical community in the HBP.

Models generated by SP4 are complemented by additional work performed by projects that have been selected via a competitive call (Cognitive Architectures).

$\to$ Bimod

$M \tilde{\otimes} N$

$P \otimes Q$

$\to \mathrm{Op}$

$$F_P(V) \tilde{\otimes} F_Q(W) \cong F_{P\otimes Q}(V \square W)$$

$$(P \circ V \circ P) \square (Q \circ W \circ Q) \xrightarrow{\tau_{V,W}} (P \otimes Q) \circ (V \square W) \circ (P \otimes Q)$$

$$((p; v_1, \ldots, v_k; p_1, \ldots, p_m), (q; w_1, \ldots, w_l; q_1, \ldots, q_n)) \mapsto (p \otimes q; (v_i w_j)_{i,j}; (p_r \otimes q_s)_{r,s})$$

$$\forall\ \frac{a : F_P V \longrightarrow F_P V'}{a^\# : V \longrightarrow P \circ V' \circ P}, \quad \frac{b : F_Q W \longrightarrow F_Q W'}{b^\# : W \longrightarrow Q \circ W' \circ Q},$$

$$\exists\ V \square W \xrightarrow{a^\# \square b^\#} (P \circ V' \circ P) \square (Q \circ W' \circ Q) \xrightarrow{\tau_{V',W'}} (P \otimes Q) \circ (V' \square W') \circ (P \otimes Q)$$

$$\underbrace{\left(\tau_{V',W'} \circ (a^\# \square b^\#)\right)^\flat}_{=: a \tilde{\otimes} b} : F_{P\otimes Q}(V \square W) \longrightarrow F_{P\otimes Q}(V' \square W')$$

$$(a' \tilde{\otimes} b') \circ (a \tilde{\otimes} b) \stackrel{?}{=} (a' \circ a) \tilde{\otimes} (b' \circ b)$$

$$V \xrightarrow{a^\#} F_P V' \xrightarrow{a'} F_P V''$$

$(a'a)^\#$

$$\xrightarrow{\tau_{V,W}} (P\otimes Q) \circ (V \square W) \circ (P \otimes Q)$$

$$\downarrow (P\otimes Q) \circ (a^\# \square b^\#) \circ (P \otimes Q)$$

$$(P\otimes Q) \circ ((P \circ V' \circ P) \square (Q \circ W' \circ Q)) \circ (P \otimes Q)$$

$$\downarrow (P\otimes Q) \circ \tau_{V',W'} \circ (P \otimes Q)$$

$$(P\otimes Q)^{\circ 2} \circ (V' \square W') \circ (P \otimes Q)^{\circ 2}$$

$$\downarrow \mu_{P\otimes Q} \circ (V' \square W') \circ \mu_{P\otimes Q}$$

$$\xrightarrow{\tau_{V',W'}} (P\otimes Q) \circ (V' \square W') \circ (P \otimes Q)$$

$$\mathcal{L}_P(P) \tilde{\otimes} Q \cup P \tilde{\otimes} \mathcal{L}_Q(Q)$$

$$\mathcal{L}_P(P) \tilde{\otimes} \mathcal{L}_Q(Q) \qquad P \tilde{\otimes} P \otimes Q$$

Methodology

Theoretical work in the HBP addresses a set of strategic issues, all related to the goal of achieving a multi-level understanding of the brain.

Bridging scales. Researchers are establishing mathematical principles that will enable them to derive simplified models of neurons and neuronal circuits from more detailed biophysical and morphological models. These mathematical principles will also facilitate the derivation of population and mean field models from simplified neuron models, and the derivation of brain region models from models of interacting neuronal populations. Other studies will model brain signals at various scales from intracellular signals to local field potentials, voltage-sensitive dye (VSD), electroencephalography (EEG) and magnetoencephalography (MEG). The results, which are validated by comparison with results from SP3, provide basic insights into the relationships between different levels of brain organisation, helping researchers choose parameter values for large-scale modelling, and guiding the simplification of models for implementation in neuromorphic technology.

Synaptic plasticity, learning and memory. SP4 researchers are developing learning rules for unsupervised and goal-oriented learning. Key themes include the derivation of learning rules from biophysical synapse models and the identification of rules for unsupervised learning giving rise to emergent connectivity patterns observed in the cortex. Outputs include learning rules transferable to large-scale brain simulations and neuromorphic technology.

Large-scale brain models. The HBP is developing simplified large-scale models of specific cognitive functions and states (perception-action; working memory and the effects of attention; biologically realistic network states – waking and sleep). These models will provide a bridge between "high-level" behavioural and imaging data and detailed multi-level models of brain physiology. Topics for modelling will include perception-action, attention, and the sleep/wakefulness cycle. These models contribute directly to the testing of architectures for neuromorphic computing systems.

Principles of brain computation. Studies in this area develop mathematical descriptions of neural computation at the single neuron, neural microcircuit and higher levels of brain organisation. The results provide basic insights into the multi-level organisation of the brain, while simultaneously contributing to the high-level design of neuromorphic systems.

SP4 applies mathematical techniques to produce models of the brain across different scales to understand the basic principles underlying neural and cognitive functions

EUROPEAN INSTITUTE FOR THEORETICAL NEUROSCIENCE (EITN)

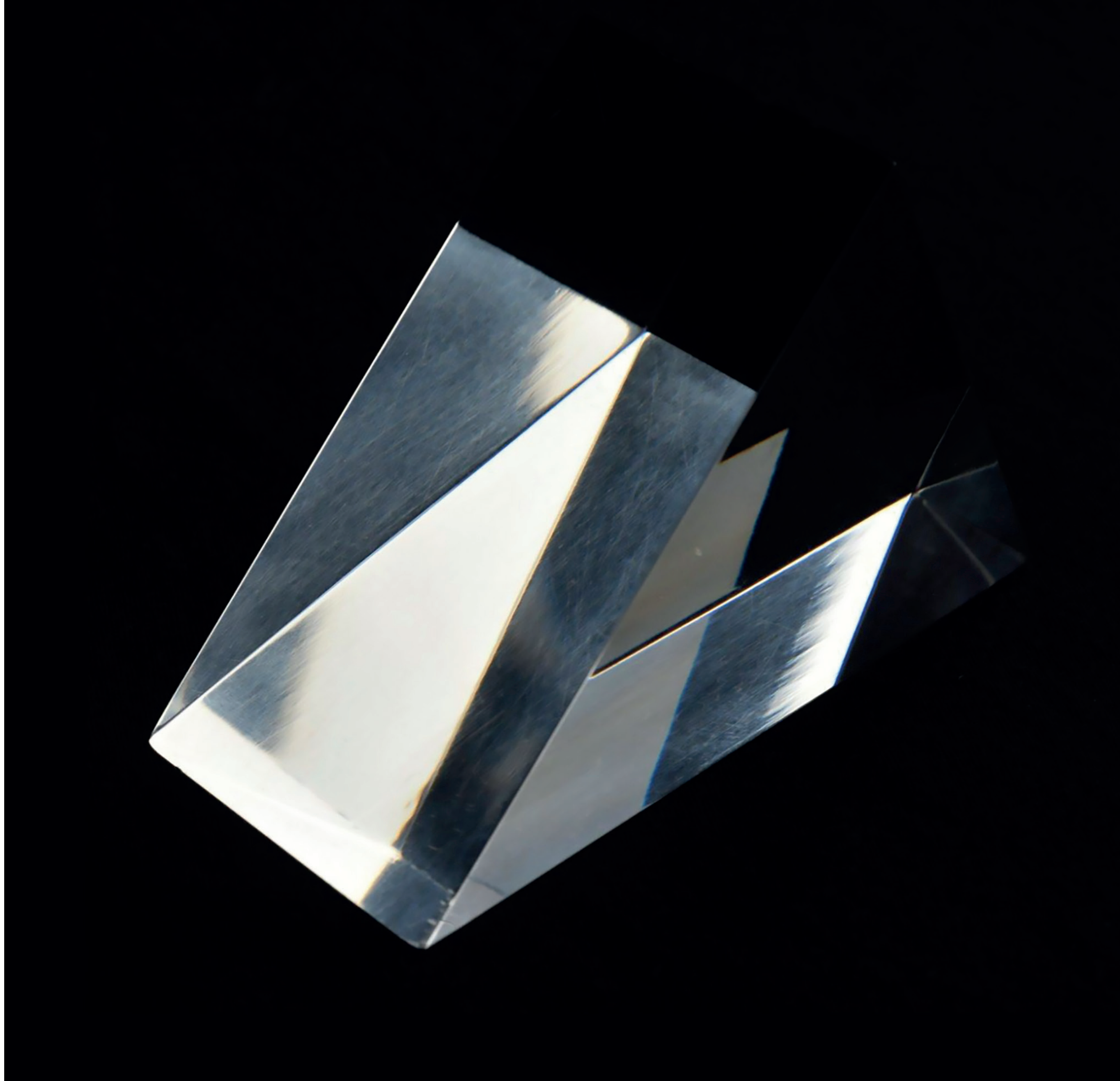
The European Institute for Theoretical Neuroscience (EITN) is a research infrastructure created as part of the Theoretical Neuroscience Division of the HBP. The EITN is operated by the CNRS and directed by Alain Destexhe from the UNIC. It is hosted in Paris, by the Foundation "Voir et Entendre" and the Vision Institute.

The EITN has been conceived as an open place to foster theoretical neuroscience activities related to the HBP, as well as to create strong interactions with the theoretical neuroscience community beyond HBP, to bring new concepts and theories to the project. The EITN finances the visit of external researchers through an extensive workshop and visitor program. It also plays a role to reinforce horizontal interactions within HBP, by organizing cross-SP meetings.

www.eitn.org

Computer Resources

SP4 requires moderate high-performance computing (HPC) resources to adjust network models before making them available to the rest of the HBP. These are provided by the High Performance Computing Platform (SP7).



Deliverables

MONTH 6 — REPORT
SPECIFICATION OF BRAIN MODELS, ALGORITHMS AND COMPUTING PRINCIPLES TO BE DEVELOPED IN THE RAMP-UP PHASE, INDICATORS OF PROGRESS AND TARGET VALUES

The report provides a detailed description of the brain models, algorithms and computing principles that SP4 plans to develop, specifies indicators of progress and defines target values for the indicators.

MONTH 12
EUROPEAN INSTITUTE FOR THEORETICAL NEUROSCIENCE

This Deliverable consists of the official opening of the planned EITN, which by the time of the Deliverable should be fully equipped and staffed, with all managerial and administrative support functions in place.

MONTH 12 — REPORT
FIRST DRAFT OF VALIDATED METHODS, ALGORITHMS AND COMPUTING PRINCIPLES

The report will provide a detailed account of the conceptual framework for first draft models, algorithms and computing principles and progress in their validation for general use.

MONTH 18
ALGORITHMS, COGNITIVE MODELS AND COMPUTING PRINCIPLES FOR THE HBP HUMAN BRAIN ATLAS: PACKAGE ONE

This Deliverable will provide an initial set of brain models, algorithms and computing principles. These will include models for perception-action, learning algorithms, algorithms for mapping models with morphologically detailed neurons to point neuron models, and brain-inspired principles of computing suitable for implementation in neuromorphic computing systems. A short report will describe each algorithm, model and principle, outline the state of validation work and provide details on how to access the model in the Human Brain Atlas.

MONTH 30 — REPORT
EITN ACTIVITY REPORT

This report will describe the activities of the EITN between its set-up in Month 12 and the end of the Ramp-Up Phase. The report will include a detailed account of the work of the resident post-docs, the visiting scientist programme, and the workshops organised by the Institute. It will also contain a roadmap for the continuation of the EITN's work in the Operational Phase.

MONTH 30
ALGORITHMS, COGNITIVE MODELS AND COMPUTING PRINCIPLES FOR IMPLEMENTATION IN HPC, NEUROMORPHIC AND NEUROROBOTIC SYSTEMS: PACKAGE TWO

This Deliverable will include algorithms, cognitive models and computing principles suitable for implementation on the HPC, Neuromorphic and Neurorobotics Platforms. The package will include models of working memory and attention and of sleep and wakefulness models based on cognitive architectures derived in SP3. A short report will describe each algorithm, model and principle, outline the state of validation work and describe how they can be tested in HPC, neuromorphic and neurorobotic systems.

Milestones

MONTH 6

- Requirements identified
- EITN workshop programme for first thirty months defined

MONTH 12

- European Institute for Theoretical Neuroscience in operation

MONTH 18

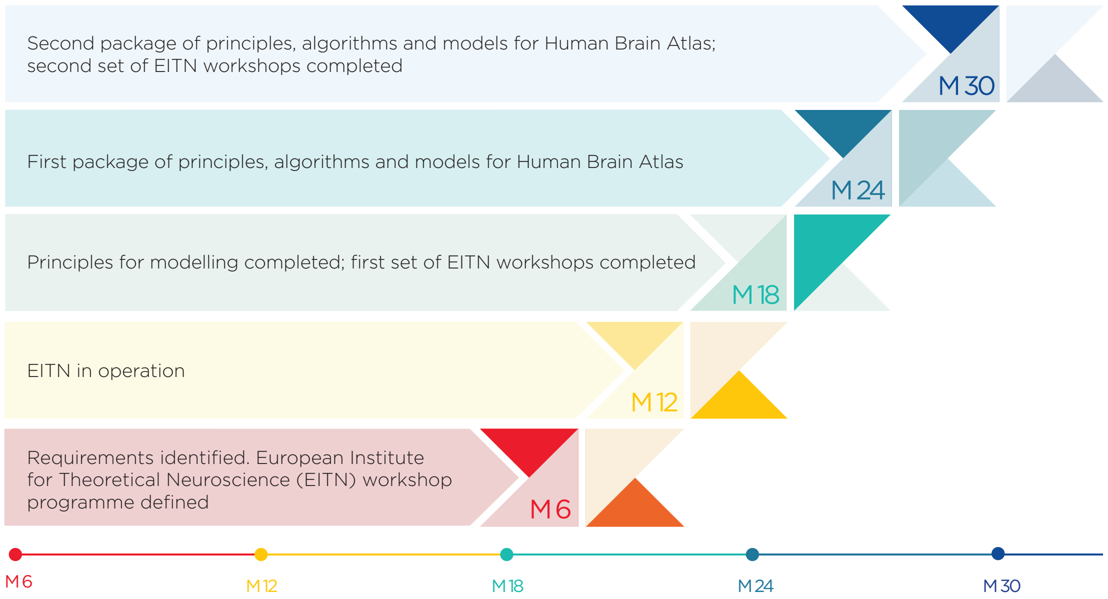
- Conceptual and theoretical foundations completed
- First set of workshops at EITN completed; Participation statistics and feedback
- Evaluation of existing computational models of astrocyte-neuron interaction for future large-scale simulations completed

MONTH 24

- First-draft principles, algorithms and models completed and deposited in Human Brain Atlas

MONTH 30

- Second-draft principles, algorithms and models completed and deposited in Human Brain Atlas
- Second set of workshops at EITN completed: Participation statistics and feedback
- Population simulator for Simulation Platform
- Summary of theoretical results PDT-RBMS
- Report to HBP: Publication(s) on framework for spiking learning algorithms and applications
- Full model of astrocyte-neuron interaction for future large-scale simulations completed
- Estimation of separation and invariance property in the retinal network



Partners

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Austria	P54	Technische Universität Graz – TUGRAZ
Belgium	P66	Universiteit Gent – UGENT
Finland	P99	TTY-SAATIO – TUT
France	P7	Centre National de la Recherche Scientifique – CNRS
	P26	Institut National de Recherche en Informatique et en Automatique – INRIA
	P107	Université Pierre et Marie Curie - Paris 6 – UPMC
Germany	P17	Forschungszentrum Jülich GmbH – JUELICH
Israel	P21	Hebrew University of Jerusalem – HUJI
	P78	Weizmann Institute of Science – WIS
Norway	P67	Universitetet for Miljø og Biovitenskap – UMB
Spain	P65	Universitat Pompeu Fabra – UPF
Switzerland	P1	École Polytechnique Fédérale de Lausanne – EPFL
	P62	Universität Bern – UBERN
United Kingdom	P70	University College London – UCL
	P110	University of Leeds – ULEEDS
	P111	University of Surrey – SURREY

Subproject Co-Leaders
Alain DESTEXHE,
Wulfram GERSTNER

SP4 Objective

"To produce simplified models of complex brain structures and dynamics; rules linking learning and memory to synaptic plasticity; large-scale models creating a bridge between 'high-level' behavioural and imaging data; and mathematical descriptions of neural computation at different levels of brain organisation."

WP4.1	**Bridging scales**	**Alain DESTEXHE - CNRS**
	Derive simplified neuron and neural circuit models from biophysically morphologically detailed models	Idan SEGEV - HUJI Alain DESTEXHE - CNRS Wulfram GERSTNER - EPFL
	Modelling brain signals at different scales, from intracellular, local field potentials, VSD up to EEG and MEG signals	Alain DESTEXHE - CNRS Gaute EINEVOLL - UMB
	Mechanistic models of cognition linked to the neural substrate by population density methods	Marc DE KAMPS - ULEEDS
WP4.2	**Synaptic plasticity, learning and memory**	**Wulfram GERSTNER - EPFL**
	Derive learning rules from biophysical synapse models	Wulfram GERSTNER - EPFL Misha TSODYKS - WIS Walter SENN - UBERN
	Unsupervised learning rules and emergent connectivity	Wulfram GERSTNER - EPFL
	Structures of spiking learning algorithms	Andre GRUNING - SURREY
WP4.3	**Large-scale models of human cognitive function**	**Gustavo DECO - UPF**
	Models for perception-action	Gustavo DECO - UPF Neil BURGESS - UCL Olivier FAUGERAS - INRIA
	Models of working memory and the effects of attention	Misha TSODYKS - WIS
	Models of biologically realistic network states; wakefulness & sleep	Alain DESTEXHE - CNRS Abigail MORRISON - JUELICH Gustavo DECO - UPF
	Computational model of astrocyte-neuron interaction for future large-scale simulations	Marja-Leena LINNE - TUT
WP4.4	**Principles of brain computation**	**Wolfgang MAASS - TUGRAZ**
	Principles of computation in single neurons and neural microcircuits	Wolfgang MAASS - TUGRAZ Alain DESTEXHE- CNRS Idan SEGEV - HUJI Henry MARKRAM - EPFL
	Novel computing systems inspired by biology	Joni DAMBRE - UGENT Wolfgang MAASS - TUGRAZ
	Closed loop analysis of population coding	Olivier MARRE - UPMC
WP4.5	**The European Institute for Theoretical Neuroscience**	**Alain DESTEXHE - CNRS**
	Setting up and administration of the institute	Alain DESTEXHE - CNRS
	Visitor and Workshop Programme	Alain DESTEXHE - CNRS
WP4.6	**Theoretical Neuroscience: scientific coordination**	**Alain DESTEXHE - CNRS**
	Scientific coordination and support	Alain DESTEXHE - CNRS

DR. ALAIN DESTEXHE
— CNRS

Alain Destexhe is physicist and Research Director (DR1) at the CNRS, in the Unité de Neurosciences, Information and Complexité (UNIC) of the Centre National de la Recherche Scientifique, France, CNRS UPR 3293. At UNIC he leads the computational neuroscience group comprising three permanent researchers, postdocs and PhD students. He is Editor in Chief of The *Journal of Computational Neuroscience*, and in the board of five other journals including *Journal of Neuroscience* and *Journal of Neural Engineering*. He has been involved in European projects (such as FACETS and BrainScaleS, where he was WP leader), and numerous grant review committees. He is author of two monographs, three edited books, and about 200 publications, including more than 100 peer-reviewed journal articles. In 2014, Alain Destexhe initiated the European Institute for Theoretical Neuroscience (EITN) in Paris, which he now leads as co-Director of SP4, in the framework of HBP.

PROF. WULFRAM GERSTNER
— EPFL

Wulfram Gerstner studied physics at the universities of Tubingen and Munich and received a Ph.D. from the Technical University of Munich. His research in computational neuroscience concentrates on models of spiking neurons and spike-timing dependent plasticity, on neuronal coding in single neurons and populations, and on the role of spatial representation for navigation of rat-like autonomous agents. He currently has a joint appointment at the School of Life Sciences and the School of Computer and Communications Sciences at EPFL, where he teaches courses for physicists, computer scientists, mathematicians, and life scientists.

PROF. NEIL BURGESS
— UCL

Neil Burgess is a professor of cognitive and computational neuroscience, a Wellcome Trust Principal Research Fellow, and Deputy Director of the UCL Institute of Cognitive Neuroscience. His laboratory investigates the neural mechanisms of memory using a combination of methods including computational modelling, human neuropsychology and functional neuroimaging, and single unit recordings in freely moving rodents. His main goal is to understand how the actions of networks of neurons in our brains allow us to remember events and the spatial locations where they occurred. After studying math and physics at UCL he did a Ph.D. in theoretical physics in Manchester and a research fellowship in Rome, before returning to UCL funded by a Royal Society University Research Fellowship and the Medical Research Council (UK).

PROF. JONI DAMBRE
— UGENT

Joni Dambre is a professor at Ghent University and head of the UGent Reservoir Lab in the Engineering Faculty. Her lab addresses theoretical research and applications of recurrent neural networks, reservoir computing, and several other machine learning techniques. The group has a special interest in neuro-inspired computing by directly exploiting the dynamics of analogue systems. As an engineer and a computer scientist, Prof. Dambre's original research addressed interconnection complexity in digital design. In 2008, she shifted towards reservoir computing in general and analogue hardware realisations of the reservoir computing concept in particular. Currently she is focused on building biologically plausible analogue reservoir architectures that can learn without global supervision, i.e. using either unsupervised or reward modulated learning. She is very interested in model abstractions that can bridge the gap between biologically plausible learning mechanisms and learning rules that are efficient in complex tasks.

PROF. DR. GUSTAVO DECO
— UPF

Gustavo Deco is Research Professor at the Institucio Catalana de Recerca i Estudis Avançats. He is also Full Pofessor (Catedrático) at the Pompeu Fabra University (Barcelona), where he is also the head of the Computational and Theoretical Neuroscience Group and Director of the Center of Brain and Cognition. He received his Ph.D. degree in Physics in 1987 (National University of Rosario, Argentina). In 1997, he obtained his habilitation (academic degree in Germany) in Computer Science (Dr. rer. nat. habil.) at the Technical University of Munich for his thesis on Neural Learning. In 2001, he received his PhD in Psychology (Dr. phil.) for his thesis on Visual Attention at the Ludwig Maximilian University of Munich. He headed the Computational Neuroscience Group at the Siemens Corporate Research Center in Munich from 1990 to 2003.

MARC DE KAMPS
— LEEDS

Marc de Kamps is a researcher in the School of Computing of the University of Leeds. His expertise is in population density techniques applied to populations of spiking neurons. He holds a PhD in high energy physics, and has considerable experience in the application of stochastic methods to neural dynamics, using a combined analytic and numerical approach. He also works on models of visual attention and neural language representation. In the past he was responsible for running the FET-funded Thematic Network nEUro-IT.net, which was instrumental in bringing together a European network of neuroscientists, engineers and computer scientists.

PROF. GAUTE T. EINEVOLL
— UMB

Gaute T. Einevoll is a professor of physics at the Department of Mathematical Sciences and Technology at the Norwegian University of Life Sciences. He is contributing his expertise on biophysical modelling of electrical signals in the brain to this Subproject. Dr. Einevoll is also interested in various aspects of multiscale modeling of early sensory pathways, including how to connect models at different levels of detail, biophysical modelling of astrocytes and their interactions with neurons, as well development of neuroinformatics tools. Dr. Einevoll received his master's in physics from the Norwegian University of Science and Technology in Trondheim in 1985 and his doctoral degree in theoretical physics from the same university in 1991. He is currently serving as the vice-president of the Organization of Computational Neurosciences, and is also a co-leader of the Norwegian national node of the International Neuroinformatics Coordinating Society (INCF).

OLIVIER FAUGERAS
— INRIA

Olivier Faugeras is a mathematician and computer scientist working in theoretical neuroscience. He is Research Director at INRIA, where he leads the NeuroMathComp Laboratory, a joint scientific venture between INRIA, the ENS (computer science department), and the JAD Laboratory at the UNSA.

DR. ANDRE GRUNING
— SURREY

Andre Gruning has been a lecturer in the Department of Computing at the University of Surrey since 2007 after postdoctoral stations at Scuola Internazionale Superiore di Studi Avanzati (SISSA) in Trieste, Italy (in neuroscience) and the University of Warwick, UK (in cognitive science). Dr. Gruning pursued his doctoral studies at the Max Planck Institute for Mathematics in the Sciences in Leipzig, Germany. There he was a member of the complex systems group, which applied mathematical concepts to natural complex systems such as neural networks, pattern formation, and systems biology. He received his diploma degree in mathematical physics from the University of Gottingen, Germany, and studied physics and mathematics in Gottingen and Uppsala, Sweden. Dr. Gruning has been working in the fields of computational, cognitive and theoretical neuroscience with publications on the computational power of neural networks, aspects of unifying reinforcement and supervised learning approaches or learning in multi-layered spiking neural networks.

PROF. MARJA-LEENA LINNE
— TUT

Marja-Leena Linne is a Research Team Leader at Tampere University of Technology (TUT, Finland) and Coordinator of the INCF national node of Finland. She holds an Adjunct Professorship in Computational Neuroscience and Neuroinformatics at TUT. Dr. Linne received her M.Sc. in electrical engineering in 1993 and a Ph.D. in signal processing and computational neuroscience in 2001. She was awarded an Academy Research Fellow position (equivalent to Associate Professor) in 2004 to establish an interdisciplinary research team in computational neuroscience. Dr. Linne's current research interests include development of new models for cellular and subcellular (both neuronal and glial) mechanisms responsible for excitability and plasticity in mammalian cortical networks. She performed experimental work on astrocytes in the early 1990s and used patch clamp, multi-electrode arrays, and microscopy in her work. Her research group also develops theoretical tools to assess the growth and structure-function relationships in local networks. Dr. Linne has developed novel stochastic approaches to model neural systems.

PROF. WOLFGANG MAASS
— TUGRAZ

Wolfgang Maass' early research was in the theory of computation in mathematics after which he moved on to computational complexity theory and the theory of learning in theoretical computer science. Since 1995 his research has focused on the extraction of principles of brain computation and learning from experimental data. Maass and Henry Markram designed the liquid computing model for understanding universal computations in cortical microcircuits. This has now become a classic reference work, inspiring numerous innovative ideas in engineering. In his current research, he is analysing the role of noise and variability in computation and learning by biological neural systems. He has published some 200 research articles and has been editor of several journals.

PROF. HENRY MARKRAM
— EPFL

Henry Markram is a professor of neuroscience at the Swiss Federal Institute for Technology in Lausanne (EPFL). He is a founder of the Brain Mind Institute, founder and director of the Blue Brain Project, and the coordinator of the Human Brain Project, which aims to construct a computerized simulation of the human brain. The HBP was selected in January 2013 as one of the European Commission's Future Emerging Technologies Flagship projects, with a grant of more than €1 billion over the next ten years. The initiative involves researchers in 80 institutions across Europe – from biologists, neurobiologists and biochemists to computer scientists and engineers. Markram believes that the HBP may lead not only to a paradigm shift in our understanding of the brain and its illnesses, but that it could also provide new, innovative concepts for designing computers and robots. Markram also aims for the Human Brain Project to spur a new approach to mental health globally.

DR. OLIVIER MARRE
— UPMC

Olivier Marre is an INSERM researcher (since 2013) in the Vision Institute (Paris), working in the team headed by Serge Picaud. He did his PhD (defended in 2008) with Yves Fregnac (CNRS, Gif-sur-Yvette) studying the visual cortex with both theoretical models and intracellular recordings *in vivo*. He then did a postdoc at Princeton University with Michael Berry, where he developed a new technique to record almost all the output neurons in a patch of retina. He is a laureate of the “ANR retour postdoc” (2012-2014) return grant to start working in the Vision Institute. He designed models of the visual cortex network during his PhD, and also did experiments to study the neural coding of natural stimuli by the neurons of the primary visual cortex of the cat. He also developed a technique to measure the retinal output sent to the brain during his postdoc at Princeton University, and showed that the recorded output can be used to precisely reconstruct the trajectory of a randomly moving object from the responses of hundreds of neurons to this stimulus.

PROF. DR. ABIGAIL MORRISON
— JUELICH

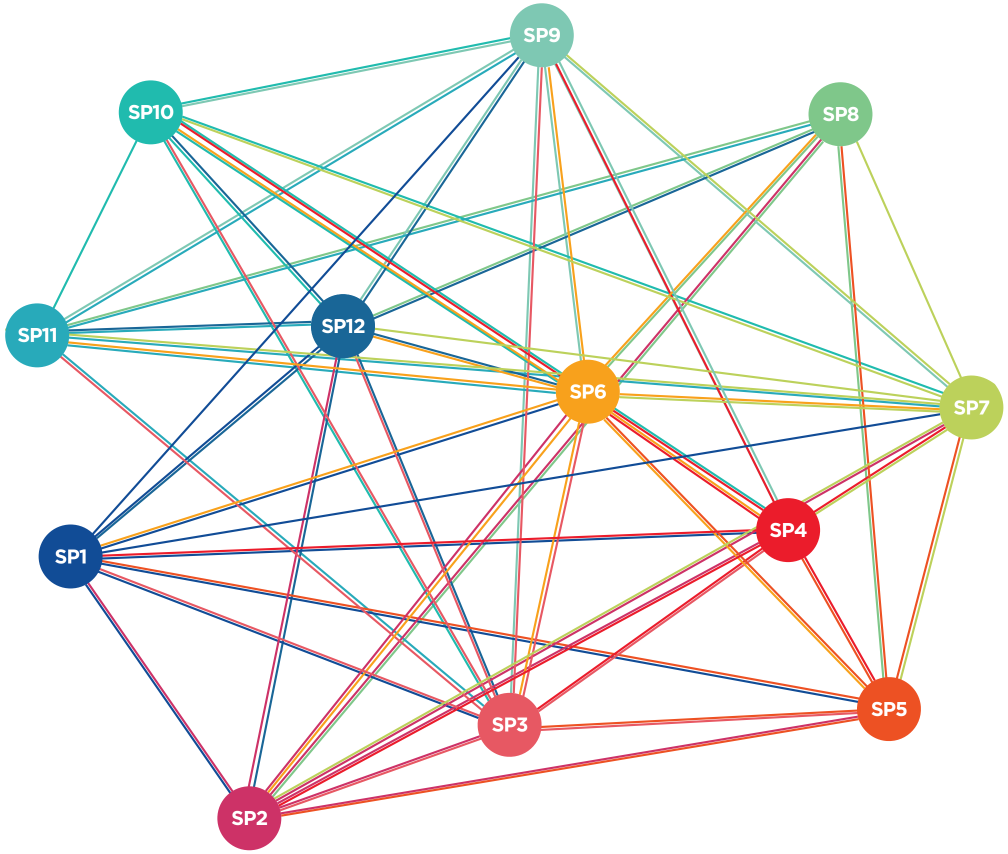
Abigail Morrison received a Master’s degree in non-symbolic artificial intelligence from the University of Edinburgh, UK and a Ph.D. from Albert Ludwigs University and the Bernstein Center for Computational Neuroscience, Freiburg, Germany. In 2006, she performed postdoctoral work at the Bernstein Center for Computational Neuroscience, Freiburg, Germany and then became a Research Scientist in Computational Neurophysics, RIKEN Brain Science Institute, Wako-Shi, Saitama, Japan (2007-2009). Between 2009 and 2012 she was a Junior Professor for Computational Neuroscience and led the Functional Neural Circuits Group, Faculty of Biology, Albert Ludwigs University, Freiburg, Germany. Since 2012, she has led the Functional Neural Circuits Group, INM-6, Forschungszentrum Jülich, and been Professor at the Ruhr University of Bochum, Germany. Since 2013, she has headed the Simulation Laboratory Neuroscience at Jülich Supercomputing Centre, Forschungszentrum Jülich.

PROF. IDAN SEGEV
— HUJI

Idan Segev is the David and Inez Myers Professor in Computational Neuroscience and the former director of the Interdisciplinary Center for Neural Computation (ICNC) at the Hebrew University of Jerusalem. He received his B.Sc (1973) in math and his Ph.D (1982) in experimental and theoretical neurobiology from the Hebrew University. His work is published in reputed journals and he has received several important awards, some for his excellent teaching abilities. He takes a keen interest in the connection between art and the brain. Prompted by an encounter with ICNC researchers, he has recently co-edited an “Artists” book with original etchings by ten top Israeli artists. Segev, the world’s undisputed leader and a pioneer on model neurons, has been instrumental in theoretically ground automated building of model neurons in the Blue Brain Project.

Theory developed in the HBP will provide a framework for understanding learning, memory, attention, goal-oriented behaviour, and the way function emerges from structure

SP4 applies mathematical techniques to produce models of the brain across different scales—from interactions among molecules to the large-scale patterns of electrical activity observed in imaging studies—and to understand the basic principles underlying cognitive functions. For example, mathematical theories of the brain can help researchers understand how experience-driven changes in the strengths of connections (synapses) allow us to learn new skills and information. As part of its work, SP4 has established a European Institute for Theoretical Neuroscience (EITN), which brings together leading mathematicians and neuroscientists from all over the world and serve as a hub for the development of innovative theory.



THE HBP'S EMPHASIS ON COLLABORATION IS EXEMPLIFIED BY THE INTERDEPENDENCE OF ITS TWELVE RESEARCH SUBPROJECTS

Subproject 1 SP1 Strategic Mouse Brain Data - Subproject 2 SP2 Strategic Human Brain Data - Subproject 3 SP3 Cognitive Architectures - Subproject 4 SP4 Theoretical Neuroscience - Subproject 5 SP5 Neuroinformatics Platform - Subproject 6 SP6 Brain Simulation Platform - Subproject 7 SP7 High Performance Computing Platform - Subproject 8 SP8 Medical Informatics Platform - Subproject 9 SP9 Neuromorphic Computing Platform - Subproject 10 SP10 Neurorobotics Platform - Subproject 11 SP11 Applications - Subproject 12 SP12 Ethics and Society

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