Joint Transnational Call 2019

for transnational research projects in synergy with the two FET Flagships

Graphene Flagship & Human Brain Project

Call pre-announcement

FLAG-ERA (the Flagship ERA-NET) will publish its third Joint Transnational Call (JTC) for collaborative research projects in synergy with the two FET Flagships by the end of 2018 at www.flagera.eu and other sources of information. The purpose of this pre-announcement is to enable interested parties to start building their consortia and preparing their proposals. It provides a tentative timeline, the foreseen list of participating funding organisations, contact points, main eligibility rules and call procedures, and descriptions of the call topics. Note that the present pre-announcement is for information purposes only: It does not create any obligation for the FLAG-ERA consortium nor for any of the participating funding organisations, and the official call announcement shall prevail.

FLAG-ERA gathers National and Regional Funding Organisations (NRFOs) in Europe and beyond with the goal of supporting, together with the European Commission, the FET Flagship initiatives, i.e., the Graphene Flagship and the Human Brain Project (HBP) Flagship. One of its main aims is to allow researchers to complement the current Flagship projects and to collaborate towards the achievement of their vision using existing or dedicated transnational, national and regional calls. In particular, FLAG-ERA aims at launching dedicated JTCs allowing researchers from several countries to jointly contribute to the Flagship goals. Note that researchers interested to work in the framework of the Flagships can also do so using other sources of funding in combination with the Flagship association mechanisms[1].

Tentative Timeline

A two-step submission procedure will be used: Applicants are invited to submit short pre-proposals; Applicants who are selected in this first step are invited to submit full proposals. A tentative timeline is provided below.

19 November 2018	Call announcement publication
10 January 2019	Information webinar
19 February 2019	Pre-proposal submission deadline
May 2019	Notification of accepted short proposals
June 2019	Full proposal submission deadline
Oct 2019	Notification of accepted full proposals
Dec 2019 - March 2020	Project start

[1] http://graphene-flagship.eu/project/partnering/Pages/Partnering-Mechanisms-under-Horizon-2020.aspx, https://www.humanbrainproject.eu/partnering-projects.

Participating NRFOs and indicative budgets

The table below provides the list of NRFOs participating to the call. Note that the list of participating NRFOs depends on the Flagship and, for the Graphene Flagship, on the sub-call (basic research or applied research and innovation). Budgets figures are indicative.

			Graphene (k€)		HBP (k€)	
Country		Funding organisation	Basic research	Applied research and innovation	Basic and applied research	Anticipated nb of fundable research groups
BE	Belgium	FNRS	200		200	2-3
		FWO	350		350	2-3
BG	Bulgaria	BNSF	100			2-3
DE	Germany	DFG	2 000			10-12
EE	Estonia	ETAg	100		100	2
ES	Spain	AEI	700			5-7
		IDEPA	200			1-2
		ICSIII			500	3-4
FR	France	ANR	1 000		1 000	8-10
GR	Greece	GSRT		900	700	7-9
HU	Hungary	NKFIH	300		300	4-6
IL	Israel	ISERD	500		500	5-7
IT	Italy	MIUR		300	300	4-6
LT	Lithuania	LMT	100		100	2-3
LV	Latvia	VIAA	300			2
NL	Netherlands	NWO			750	3
RO	Romania	UEFISCDI		250	250	3-4
SE	Sweden	VINNOVA		750		2-4
		VR	750			2-4
SI	Slovenia	MIZS	420		210	3
SK	Slovakia	SAS	120		120	2
TR	Turkey	TUBITAK	2 500			10-15

FLAG-ERA

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For further information, please visit us on the FLAG-ERA website: http://www.flag-era.eu.
For general questions about the JTC and national eligibility criteria, please contact your national or regional contact point (see above).
For technical questions regarding the JTC (electronic submission, etc.), please contact the Joint Call Secretariat: serguei.fedortchencko@agencerecherche.fr.

Eligibility of Consortia

Consortia must be international. They must involve **at least**

- **3 partners requesting funding from 3 participating countries, or**
- **2 partners requesting funding from 2 participating countries and a partner from another country securing its own funding as a Flagship Core Project partner.**

In both cases, partners requesting funding may be Flagship Core Project members.

In any case, the consortium coordinator must be a partner requesting funding (and be eligible for funding) from an organisation participating in the call.

While applications will be submitted jointly by groups from several countries, each group will be funded by its respective national or regional funding organisation. The applications are therefore subject to **eligibility criteria of individual funding organisations**.

Duration

Projects may be funded for a period of **up to 3 years** and according to individual funding organisation regulations.

Procedure

A **two-step submission procedure** applies. At each step, a **joint transnational proposal** (or pre-proposal for the first step) shall be prepared by the applicants, and must be submitted electronically by the coordinator. The proposal shall include a draft application to become a Flagship Partnering Project.

Evaluation and Selection of Proposals

Proposals are assessed by an independent international Scientific Evaluation Panel with the help of external reviewers. They are evaluated and ranked according to the following criteria:

1. Excellence (Scientific and/or technological quality);
2. Implementation;
3. Impact.

On the basis of the ranking and of available funding, the Call Steering Committee, composed of the NRFOs participating in the JTC, will prepare a list of projects invited to submit a full proposal (after the 1st step) or recommended for funding (after the 2nd step).

Association to the Flagship

Projects recommended for funding will be invited to proceed with the formal association to the Flagship, using the Flagship standard association procedure. Any issue at this stage will be treated through classical project risk management.

Research areas

The FLAG-ERA JTC 2019 comprises two topics, one for each Flagship. Each topic covers a specific list of research areas listed below and described in the following pages. The Graphene part of the call is sub-divided into two sub-calls, one for basic research and one for applied research and innovation. All Graphene topic areas are open to both sub-call, and it is up to the applicants to decide under which sub-call they apply, taking into account the lists of participating countries (cf. section 2) and the weights on the evaluation criteria (cf. section 6). Relevant parts of the Flagship and contact points for each area are provided on the call web page.

Graphene JTC areas

1. Synthesis and characterization of layered materials beyond graphene
2. Graphene and related materials (GRMs) for Quantum Technologies
3. Optimized GRM-based tunnel barriers for efficient spin injection and detection into graphene under operational conditions
4. Spin torque and layered-materials-based memory building block
5. Synthesis of monolayers of non-layered compounds
6. Bacterial degradation of GRMs
7. Osteoinductivity and immunisation capacity of GRMs
8. Soft graphene-based materials for tissue engineering
9. GRM-based large-area light emitters and arrays
10. Low temperature growth of layered semiconductors for flexible applications
11. Nanofluidics based on GRMs
12. CVD growth of graphene on insulators
13. Sensors from GRMs and their heterostructures
14. Passive components for radio frequency electronics based on GRMs
15. Infrared photodetectors based on GRMs and their heterostructures
16. LIDAR based on GRMs for autonomous vehicles
17. Moore's law continued through GRMs
18. GRM-based tandem solar modules
19. Graphene-based cathode materials for Li-ion batteries
20. Re-usable templates for graphene production

HBP JTC areas

1. Development and maturation of cognitive processes and multisensory integration at micro- and macro-scales
2. The role of neurotransmitter systems in human cognition
3. Subcortical structures: from cognition to action
4. The neuroscience of decision-making
5. Studies on biological deep learning and combined declarative and working memory
6. Disease modelling and simulation
7. Single cell RNA sequencing of human and mouse brain
8. Predictive neuroinformatics: A trans-species approach
9. Testing neuronal models at multiple scales
10. Automated construction and analysis of models of neurons and networks
11. Reconstruction of neuronal morphology from microscopic image data
12. Neuron data format standardization

Graphene JTC areas

1. Synthesis and characterization of layered materials beyond graphene

New layered semiconducting and metallic crystals, or layered bulk compounds that can be exfoliated into monolayers, have the potential to accelerate optoelectronics and electronics developments aiming at post-CMOS technologies. There is a need to broaden the range of such materials available for device prototyping and industries in Europe and to build up European capabilities in MBE, CVD and/or ALD growth of these materials. Progress can be delivered by combining growth/synthesis and characterisation expertise and facilities, and proposals should plan both growth/synthesis activities and suitable structural, optical, scanning microscopy of the newly produced layered materials, with access to the necessary facilities. Developments should be benchmarked against same materials already produced using similar methods worldwide.

Keywords: Molecular beam epitaxy (MBE), Chemical vapour deposition (CVD), Atomic layer deposition (ALD)

2. Graphene and related materials (GRMs) for Quantum Technologies

Functionalities offered by GRMs and their heterostructures can be exploited to extend the materials platform for electron- and photon-based Quantum Technologies (QT). There are also possibilities to develop better performing devices for quantum information processing such as spin, charge or flux qubits, single-photon emitters for cryptography applications, and sensors and detectors with performance enhanced by quantum entanglement. New device concepts for QT enabled by GRMs can also be proposed. Proposals should demonstrate the ability to fabricate and test the new systems, taking the demonstrators to the suitable level of device prototypes.

Keywords: Quantum technologies

3. Optimized GRM-based tunnel barriers for efficient spin injection and detection into graphene under operational conditions

For the implementation of graphene spintronics devices it is highly desirable to achieve spin injection/detection efficiencies approaching 100%, using a technology which is compatible with GRMs which hosts the spin transport. Tunnel barriers of hexagonal boron nitride (hBN) have shown a significant, but not yet understood, increase of injection/detection efficiencies. The role of the number of layers as well as layer orientation is currently unknown. Thorough understanding of the relevant physics and technology is now needed to make progress for GRM-based spintronic devices, in particular addressing the role of elevated voltage and temperature bias. The latter is believed to significantly affect the spin propagation, especially in the presence of hot carriers.

Keywords: Spintronics, spin injection, spin detection

4. Spin torque and layered-materials-based memory building block

Magnetic random access memory (MRAM) is an emerging non-volatile memory (NVM) whose memory cell comprises a magnetic tunnel junction (MTJ). It has exceptional characteristics, but needs to keep improving performances to become a leading technology. By coating magnetic materials with GRMs, it has been predicted and demonstrated that a considerable improvement of the perpendicular magneto anisotropy (PMA) can be achieved, as well as a great enhancement of writing and reading energies. These parameters are key figures of merit for MRAM technology. By leveraging paths to integrate these new materials in MTJ following industrial processes, a major impact on such spin-torque-based technologies can be expected. Proposals should target the integration of layered materials in spin-torque-based MRAM devices in a fab environment and the development of key-in-hand solutions enabling further large-scale commercial production of layered-materials-based spintronic devices.

Keywords: Spintronics, spin torque technology, Magnetic random access memory (MRAM)

5. Synthesis of monolayers of non-layered compounds

Layered Materials (LMs) can be superconductors, insulators, metals or magnetic. Non-layered materials also exhibit a broad range of functionalities, such as ferroelectricity, ferromagnetism, superconductivity, etc. New approaches have appeared that allow large-scale synthesis of monolayers of non-layered compounds. Large-scale synthesis strategies should be developed for monolayers of non-layered materials that can be combined in multifunctional heterostructures with conventional layered materials. Integration of conventional LMs with well-established materials in current technological applications based on non-layered materials exhibiting technologically relevant ferromagnetism, ferroelectricity, high Tc superconductivity, etc., can have applications in fields such as renewable energies and information technologies. Proposals should aim at enlarging the existing LM platform with the inclusion of non-layered materials exhibiting functionalities such as ferroelectricity, ferromagnetism, superconductivity, etc. Improvements are expected in the number of monolayers of the non-layered materials synthesized and in the integration of such layers with LMs in multifunctional heterostructures.

Keywords: Synthesis, non-layered materials, hetero-structures

6. Bacterial degradation of GRMs

One fundamental aspect of GRMs ecotoxicology concerns the assessment of possible ways for the degradation of GRMs released into the environment. Bacterial communities play a major role in biogeochemical cycles. Their metabolic versatility allows them to use organic materials dispersed in the environment as sources of reduced carbon thanks to extracellular degradation processes. Furthermore, microbial communities are known to colonize contaminated sites and have the ability to metabolize recalcitrant xenobiotics. The diversity, versatility and plasticity of bacteria make them the best candidates among all living organisms to study the degradation of GRMs and GRM-based composites and devices. Best subjects are bacteria of graphite ore fields and/or with intense extracellular oxidative activities. Proposals should investigate the capacity of bacterial communities to degrade GRMs and composites or polymers and devices that contain such materials.

Keywords: Bacteria, GRM-based composites, degradation, remediation

7. Osteoinductivity and immunisation capacity of GRMs

Nanosystem-based strategies in bone tissue engineering have seen recent progress on several fronts. GRMs, due to their unique structure and mechanical proprieties, facilitate the osteogenic differentiation of mesenchymal stem cell (MSC) and enhance bone regeneration. Furthermore, depending on their physicochemical properties, GRMs can be selected for exerting distinct molecular effects on the immune system. The immune system plays a key role in osteoblast differentiation and consequently on bone formation. In osteoimmunology, GRMs have emerged as new systems in clinical strategies for bone formation and regeneration. There is a need to identify the most suitable GRM-based composites able to boost bone formation and osteogenesis.

Keywords: Immune cells, GRM-based composites, bone formation, mesenchymal stem cells

8. Soft graphene-based materials for tissue engineering

Mimicking natural conditions of tissue growth is a major challenge. A new approach can be based on the design of soft graphene-based functional materials. A chemical design of the hybrid structure must control the final physicochemical properties, affording special sizes and shapes for localization of cells. Graphene is known to promote cell adhesion and can enhance viscoelastic characteristics, which have a large influence in cellular behaviour and differentiation. Moreover, scalable designs may allow the preparation of smart materials, with self-healing ability and control delivery of biomolecules, to enhance the innate reparative capacity of cells.

Keywords: Tissue engineering, viscoelastic properties, artificial organs, controlled delivery

9. GRM-based large-area light emitters and arrays

Standard OLED technology offers a good solution for flexible light sources and displays, but it suffers from rather low brightness. Solid-state emitters are considered as alternative to surpass this problem, but are not adequate for flexible applications. New GRMs with efficient light emission at all colours of the visible spectrum and high brightness would also be suitable for flexible and transparent substrates and could lead to substantial innovations. The goal is to develop a novel competitive LED technology with sufficient efficiency, brightness, and dimensions for (micro-) display and lighting applications. Priorities include large-area devices and large-area/wafer-scale growth of GRMs with efficient light emission of the visible spectrum, preferably including the short-wave infrared, and high brightness and fabrication of pixel arrays, which will also be suitable for flexible and transparent substrates.

Keywords: Heterostructures, electrically driven light emitters, displays, lighting

10. Low temperature growth of layered semiconductors for flexible applications

Layered semiconductors are promising candidates for logic and optoelectronic functions in future flexible electronics applications, due to their flexibility, transparency and, in many cases, direct bandgap. The feasibility and prospects of these materials in commercial products would benefit significantly from a technology allowing their direct deposition on polymer sheets, where the thermal budget is limited to below 350ºC for polyimide and below 200ºC for most other polymers. The goal is to develop a scalable process for the low-temperature deposition of stable layered semiconductors and include characterization of their electrical and optical properties.

Keywords: Transition metal dichalcogenides (TMDs), deposition, low-temperature

11. Nanofluidics based on GRMs

GRMs can be used to develop structures or laminates for nanofluidics with a significant performance improvement over current technologies, or offer new opportunities only made possible by layered materials. Proposals are expected to outline a route towards higher technology readiness levels and, ultimately, new industrial products. They should combine experimental and theoretical efforts (mesoscale modelling, molecular dynamics simulations), based on expertise in layered materials fabrication, characterisation and modelling of their relevant structural and nanofluidic properties.

Keywords: Nanofluidics, nanochannels; ionic transport

12. CVD growth of graphene on insulators

Large area CVD growth of graphene has made significant progress over the last decade. However, the difficulties in transferring the material to target substrates hamper its use in some applications. Growth techniques enabling synthesis of graphene directly on a dielectric substrate should be developed. Direct large area CVD growth of graphene on insulators glass, oxides (such as TiO_2, SiO_2), ceramics, etc., would open a range of application that, if achieved at low temperature compatible with relevant industrial processes, would widen the application scope of graphene in functional architectures, home automation, photovoltaics, functional ceramics, etc.

Keywords: CVD growth, graphene, insulators, low temperature

13. Sensors from GRMs and their heterostructures

GRMs have many advantages for sensors. The sensitivity to mechanical signals is enhanced when suspended, lower heat capacitance leads to higher temperature changes when radiation is absorbed, and electrical properties are more affected by surface effects and less by substrate influences. GRMs can thus be used to develop sensors such as microphones, bolometers, Hall sensors, photonic sensors, gas sensors, biosensors and atomic filters.

Keywords: Suspended GRMs, freestanding GRMs, sensors

14. Electronic radio-frequency devices and systems based on GRMs

While field effect transistors based on GRMs have been intensively studied, GRM-based electronic radio-frequency components such as antennas, capacitors, inductors, resonators, diodes, varactors, etc., are less well explored. This gap should be closed and concepts for realizing RF devices and systems should be developed. Examples of systems include antenna arrays, power detectors, band-pass filters, phase shifters and rectifiers. Targeted applications include the Internet-of-Things, mobile communication, sensors and energy harvesting.

Keywords: RF electronics, RF engineering, IoT

15. Infrared photodetectors based on GRMs and their heterostructures

Existing technologies for infrared photodetection are either high cost, requiring cooling, or have poor resolution. This topic targets the development of photodetectors for the wavelength range between 2 and 20 µm. Essential requirements include detectors based on large-area materials (e.g. CVD grown), pixel size <20 µm, and improved detectivity and speed compared to Si bolometers. The goal is to translate the concept of semi-conductor quantum-well photodetectors to GRM heterostructures, but exploiting the specific advantages such as absence of lattice-matching requirements.

Keywords: Photodetection, Infrared

16. LIDAR based on GRMs for autonomous vehicles

LIDAR (LIght Detection And Ranging) is a light range finder system for real time accurate detection of in depth images. The main application is obstacle warning for vehicles but also for remote control of unmanned vehicles, smart buildings/smart cities, drones and self-driving cars. Automotive, industrial robots and drones are the potential largest market and the LIDAR can be used either for safety (monitoring drowsiness and distraction), in field monitoring and/or for self-driving. High index contrast photonic integrated circuits including graphene for tuneable phase shifting is the intended technology for the realization of the LIDAR transmitter scanning head. The goal is to develop a compact, energy-efficient scanning head with the potential for large-scale, low-cost manufacturing.

Keywords: Silicon photonics, graphene photonics, LIDAR

17. Moore's law continued through GRMs

In classical semiconductor materials, ultimately scaled channels below 10 nm will lead to a drop in the carrier mobility due to increased surface roughness scattering. One possible disruptive way out of this predicament is the use of layered materials such as transition metal dichalcogenides (TMDs), with good mobility even in the single-layer limit. This will allow scaling of the device size beyond the limits of Moore's law for 3D materials. At flake level, interesting devices have been demonstrated. The objective is to bring growth and integration schemes closer to applications. For that purpose, short channel devices should be demonstrated.

Keywords: Semiconductors, transition metal dichalcogenides (TMDs), scaling, Moore's law

18. GRM-based tandem solar modules

Fast and reliable in-situ, single-step, techniques for rapid and inexpensive fabrication of GRMs-based solar modules are needed for their industrialization. A critical requirement is that the fabrication processes must be compatible with the low-temperature plastic materials considered as substrates in flexible solar modules or the bottom inorganic subcells. It is essential to develop non-contact processes, in-situ, that do not rely on the use of chemicals or high temperatures and can be compatible with sheet-to-sheet or roll-to-roll manufacturing of CIGS/perovskite solar modules. Areas of special interest are: (i) In-situ techniques that are able to a) pattern and/or shape in real-time and/or b) modify the chemistry of GRM device components in real-time, without physical contact between components and processing tools; (ii) Post fabrication in-situ and non-contact techniques that are able to process, non-destructively, integrated GRM based tandem solar modules.

Demonstrators should target the in-situ processing of mono- or multilayer GRM components or post-fabrication processing of GRM-based solar modules.

Keywords: In-situ processes, flexible electronics, large-area optoelectronic devices, Roll to roll/sheet-to-sheet processing.

19. Graphene-based cathode materials for Li-ion batteries

The integration of highly conductive matrices in Li-ion battery cathode formulations will create new opportunities in terms of high power deploying and fast charging. In order to combine high-capacity with improved kinetic properties, research around S and Li-rich intercalation cathode materials as well as cathode material-graphene engineering is needed. In particular, power densities and energy densities exceeding commercial high-end Li-ion batteries values (200 $Wh.kg^{-1}$ and 300 $W.kg^{-1}$, respectively) are targeted as minimum requirements.

Keywords: Li-ion batteries, high-power batteries, graphene, Lithium intercalation, cathode

20. Re-usable templates for graphene production

Chemical vapour deposition is one of the most promising methods for graphene production. The resulting quality (grain size, defects, number of layers) has a strong dependence on the "template" used. The template is defined here as the metal foil (for roll to roll) or catalyst stack plus wafer (for wafer-scale production). A lot of effort/expense is put into creating the template, such as single crystal metallic foils or single orientation thin films on substrates. Often the template is destroyed during graphene transfer. Therefore, methods for preparing, cleaning and reusing these substrates are needed for graphene production to be truly cost effective. Proposals are sought to demonstrate re-usable templates for graphene production (i.e. same quality – defects, grain size number of layers obtained/transferred over >5 uses) and means of producing and regenerating these templates.

Keywords: Catalyst, Chemical Vapour Deposition

HBP JTC areas

Projects should contribute to the aims of the HBP and address ambitious research questions in the field of brain research including medical research, brain inspired technologies, robotics & computing and/or contribute to technological development. The proposed activities should be based on the latest scientific knowledge, and include innovative concepts that bring the field closer to the solution of a concrete and important problem in an interdisciplinary research approach. **Objectives should be realistic and measurable, and reproducibility should be ensured.** Proposed activities should demonstrate their potential to benefit from and/or contribute to the HBP ICT platforms (Subprojects 5-10). Ideally they cut across existing HBP Subprojects, including neuroscientific and platform Subprojects and/or the 'Ethics and Society' Subproject.

1. Development and maturation of cognitive processes and multisensory integration at micro- and macro-scales

The fields of Neuroscience, Cognitive Neuroscience, AI and Neuroengineering are making strong and partially successful efforts to understand the microcircuit and meso-scale levels of cognitive architectures in the brain. Insights are accumulating in the roles played by e.g. interneurons, principal neurons, and dendrites in cognition, and mesoscale imaging tells us which larger brain systems are involved in memory, decision-making, planning, sensory processing and consciousness. Much less is known about how these small- and large-scale structures come to be organized and properly wired during development and how they are affected by experience-dependent plasticity during postnatal life.

Cognition and multisensory integration are considered high-level processes, depending on millions of neurons, often spread out across multiple, connected brain areas. The novelty of this topic lies in studying how these high-level processes arise out of the mostly low-level growth and synaptic processes identified from cellular and molecular studies on brain development. We have very little understanding on how the brain "bootstraps" this low-level functionality into higher cognitive functions such as full-blown scene perception and how the different sensory modalities are integrated in a growing body.

Proposals should address the specific involvement of neuronal subtypes (interneurons, excitatory cells) in cognitive and multisensory integration processes, circuit dynamics, role of experience on the development of cognition and multisensory integration including neuronal models of these processes across development. Projects can include translational studies for autism, schizophrenia and other neurodevelopmental diseases addressing the development of cognition and/or multisensory integration.

Keywords: Cognition, multisensory integration, neurodevelopment, experience-dependent plasticity, brain architectures, neuronal modelling, multiscale systems

2. The role of neurotransmitter systems in human cognition

Neurotransmitters such as dopamine, noradrenaline, serotonin, acetylcholine, glutamate, GABA and opioids play a crucial role in all aspects of cognition. Many psychiatric and neuropsychological disorders, including depression, addiction, attention deficit hyperactivity disorder (ADHD), obsessive–

compulsive disorder (OCD) and Parkinson's disease, are characterized by dysfunctioning neurotransmitter systems, yet their precise roles are not well understood. With an increasing number of neuroscience methods available to measure or manipulate neurotransmitter functioning in humans with increasing specificity, it becomes possible to build the bridge between lower-level neuroscience research in animals and system-level neuroscience research in humans. Such research on neurotransmitter systems in humans yields important knowledge for the emerging field of computational psychiatry aiming at improved disease classification and treatment selection.

This topic goes beyond the commonly employed clinical, genetic, resting state and/or structural imaging methods and invites proposals to integrate the data generated using these techniques with cognitive computational approaches to understand the role of neurotransmitters in cognition and brain disease. It is expected that linking molecules to brain activity and cognitive function has the potential to unify molecular system-level and cognitive neuroscience.

Keywords: Neurotransmitters, human cognition, pharmacology, psychiatry

3. Subcortical structures: from cognition to action

Crosstalk between subcortical and cortical structures strongly influences cognitive processes and their translation into action. To develop brain simulations for the study of human behaviour, mental illness, and robots that can act as autonomous agents that interact with humans, a strong integration of subcortical brain function is necessary.

This topic concerns research projects aiming at the molecular and cellular characterization of subcortical structures such as the thalamus, basal ganglia, tectum, amygdala, hypothalamus and brain stem. The proposals should consider subcortical connectivity and the functional properties of these subcortical structures during behaviour in animal models and/or humans, as well as their functional and/or anatomical interaction with the cortex. This knowledge should serve as the basis for improving models and simulations of the healthy and diseased brain.

Keywords: Thalamus, basal ganglia, tectum, amygdala, hypothalamus and brain stem, cortical loop

4. The neuroscience of decision-making

Each day our brain makes thousands of decisions. We are aware of few of them. Decision-making processes are central to behavioural, cognitive and psychological neurosciences. Understanding and modelling the basic neural processes and computations that underlie decision-making is crucial to understand how the healthy brain functions and how disorders (psychiatric, neurologic disease, drug abuse) affect the underlying processes. This area is also of great importance for the development of performant artificial systems (i.e. in robotics).

This topic includes different aspects of decision-making, from the investigation of brain and neural mechanisms using experimental and modelling approaches, to the application of decision-making knowledge to artificial systems such as neuro-robotics. The role of neurotransmitter systems, neuronal subtypes and cortical and subcortical circuits involved in decision-making fall into the scope of the present topic.

Keywords: Decision-making, neuro-robotics, modelling, psychiatry, neurotransmission, neural processes and computation

5. Studies on biological deep learning and combined declarative and working memory

Deep learning networks have turned out to be very efficacious in addressing complex problems such as playing games (e.g. Go), image classification and object recognition. The next challenge is to study how biological brains implement these high-level functions in actual living neural networks. The present research area aims to address whether less realistic properties of deep learning algorithms could be replaced by more biological properties, i.e. realistic bioelectric behaviour of neurons, and how the functionality of networks could be further augmented using knowledge about the brain.

One particular challenge is to combine multi-layered feed-forward networks (styled roughly after the neocortex) with systems for declarative and/or working memory (resembling the hippocampal formation, frontal cortex and connected structures). This way, high-level information from deep learning can be stored temporarily, contextualized and semanticized. Thus, the model can assign meaning to the outputs from a deep-learning network. The aim would be to gather empirical data from humans and rodents on such combined models, and test them in multi-scale models and neuromorphic computing devices.

Keywords: Deep learning, object recognition, biological brain, biological plausibility, declarative memory, working memory

6. Disease modelling and simulation

The objective of this call topic is to promote clinical proof-of-concept studies and research projects related to the modelling and simulation of different brain diseases. Strong interaction with the Medical Informatics and Brain Simulation Platforms is highly encouraged. Through these platforms, projects will have access to data and bioinformatics methods (machine learning, data intensive network analysis, pathways analysis in large volume of data) to gain new clinical insights, derive mechanisms of disease causation, identify relevant brain networks across healthy subjects and patients using imaging data, and study mechanisms of action of known therapeutic agents. Possible research themes include mechanisms of disease causation, mechanisms of action of known therapeutic agents, screening of drug candidates, and developing both hypothesis and data driven models of disease directly constrained by experimental data in human and animals.

Keywords: Disease modelling, disease classification, network analysis, brain disease, Alzheimer's disease, epilepsy

7. Single cell RNA sequencing of human and mouse brain

Single cell RNA sequencing allows categorizing brain cells based upon gene expression. In combination with GWAS data from human brain disease, this allows to predict which cell types are involved in human brain disease processes. These cells can then be manipulated (e.g. with chemogenetics) or targeted to create iPSC-models and studied. This provides a strong translational tool to unravel human brain diseases at a functional level. Knowledge of which GWAS genes are expressed in which cells is also helpful to increase the power of neuroimaging genetics since only a limited amount of genetic variants would need to be tested for explaining variance in brain response. Single-cell RNA sequencing techniques can be used to unravel human brain diseases by investigating single cells from well-characterized affected and unaffected human brains and mouse models of brain disorders. Further aspects of interest include stratification of scRNA findings using large-scale GWAS data and validation of the underlying mechanisms using animal and cellular models.

Keywords: Single-cell RNA sequencing (scRNA-seq), genome-wide association study (GWAS), induced pluripotent stem cell (iPSC), chemogenetics, bioinformatics

8. Predictive neuroinformatics: A trans-species approach

The principal goal of the HBP is to build the infrastructure necessary for analysing, modelling and ultimately simulating the human brain. A key challenge is to obtain appropriate parameter values for this human model. There is a fundamental gap in human data that can only be filled by data generated in other animal species. Research projects on this topic are expected to develop, adapt and implement the appropriate machine learning techniques to support trans-species prediction; to use new experimental approaches to acquire the data necessary to support trans-species prediction approaches; or design and build the infrastructure to support trans-species prediction in a robust and sustainable way.

The expected outcome would be the prediction of human brain properties based on the analysis of structural, behavioural, genetic and cognitive convergences among species.

Keywords: Machine learning, translational neurosciences

9. Testing neuronal models at multiple scales

Neuronal models aim at identifying a set of cellular properties (morphology, conductivity, connectivity) and computing them to predict the activity of neurons relevant to brain function. A great diversity of models has been developed at multiple scales in space, time and complexity, and span from large brain regions to the subcellular level. In order to test these models, their predicted responses must be confirmed by using suitable experimental tools for neural stimulation and recording at the relevant scales, including field stimulation electrodes and multi electrode arrays (both implanted and external), transcranial magnetic stimulation and functional magnetic resonance imaging, and photostimulation and activity recording using light (e.g. optogenetics). Research projects on this topic are expected to define a set of tools to test, compare, improve and validate neuronal models at different scales to be used by the community.

The following questions are expected to be addressed using experimental tools for neurostimulation that test, compare, improve and validate neuronal models at multiple scales, from brain regions to dendritic spine level: Can neuronal models achieve better predictive accuracy by embedding realistic structural and electric information (obtained from high-resolution microscopy and electrophysiology experiments)? How do neuronal models perform at different spatiotemporal scales? Can their complexity and use of computational resources be optimised? What are the advantages of closed-loop stimulation?

Keywords: Neuronal model validation, electric, magnetic, optic recording and stimulation

10. Automated construction and analysis of models of neurons and networks

Research projects on this topic should develop methods for the automated construction and revision of models of the dynamics of neurons and networks. The methods should take as input both data as well as existing domain knowledge (including existing neuronal models from model databases). The search through the space of model structures should be combined with multi-criteria optimization to obtain models that fit the data and satisfy additional on-demand criteria.

Keywords: Automated modelling, dynamic systems, differential equations, neuronal models, model database

11. Reconstruction of neuronal morphology from microscopic image data

Characterizing the 3D morphology of individual neurons and axons from different nervous (sub)systems is fundamentally important for elucidating the relationship between brain structure and function. Advanced microscopes allow high-resolution imaging of neurons in vitro as well as in vivo. Yet the systematic characterization of even simple brain circuits at the level of their individual neurons is still limited by the lack of robust computer algorithms for fast and accurate reconstruction of neurons from the image data. This topic concerns research projects proposing the development of new computational methods and software tools capable of reconstructing neuronal morphology based on microscopic data from different animal species, brain locations, neuronal tracing, histological and/or imaging protocols.

Keywords: Neuron reconstruction, microscopy, image analysis, brain connectivity

12. Neuron data format standardization

The way neurons (data) are mapped on memory has an impressive impact on performance when simulations are run in a supercomputer. This is particularly true for applications such as the simulation of the human brain, where the data, which come from the discretization of the neurons, presents a non-structured layout. Using a standard format, the scientists could advance much faster in their research, but it is important to spend the necessary time to establish the desired standard. This topic concerns research projects proposing and developing unified data formats for neuronal simulation.

Keywords: Data layout, standard, memory, performance, fast research