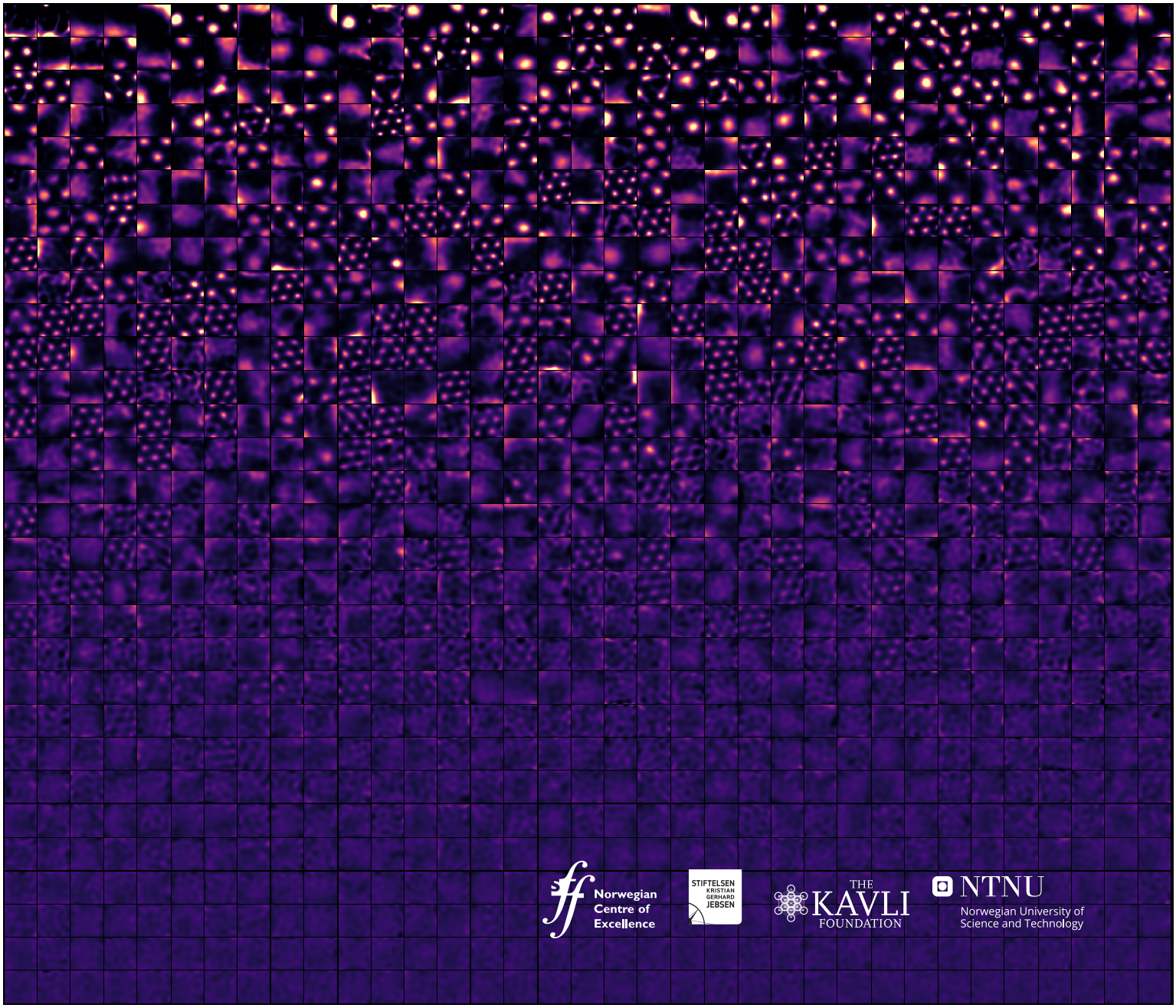
Kavli Institute
for Systems Neuroscience

2019 AT A GLANCE

Graphic summary of the annual report



Norwegian Centre of Excellence

STIFTELSEN KRISTIAN GERHARD JEBSEN

THE KAVLI FOUNDATION

NTNU
Norwegian University of Science and Technology

Courtesy of Karoline Horde / Kavli Institute for Systems Neuroscience".

Dear reader

This folder presents facts and figures as well as a summary of highlights for the institute. We hope you enjoy our annual report in the new format.

The Kavli Institute Directors

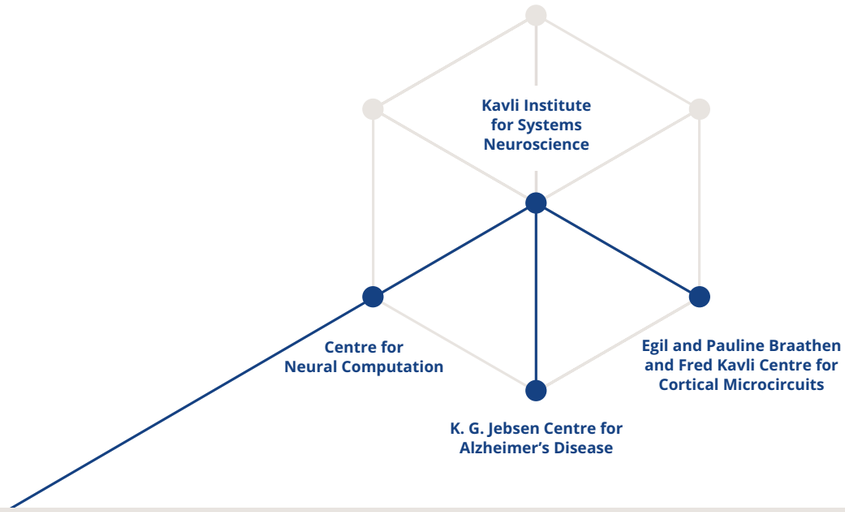
May-Britt Moser
Scientific Director

Edvard Moser
Scientific Director

To understand the emergence of higher brain functions

Our Vision

Organizational chart



GROUP LEADERS

MAY-BRITT MOSER
Moser Group
Scientific Director

EDVARD MOSER
Moser Group
Scientific Director

MENNO WITTER
Witter Group

JONATHAN WHITLOCK
Whitlock Group

YASSER ROUDI
Roudi Group

CLIFFORD KENTROS
Kentros Group

EMRE YAKSI
Yaksi Group

RAPHAEL KAPLAN
Doeller - Kaplan Group

The Kavli Institute and its Centres

KAVLI INSTITUTE FOR SYSTEMS NEUROSCIENCE (KISN) is a leading research institute founded by Nobel Laureates May-Britt Moser and Edvard Moser in 2007 to investigate the emergence of higher brain functions.

The neuroscience research institute now comprises three research centres:

- Centre for Neural Computation (CNC)
- Egil and Pauline Braathen and Fred Kavli Centre for Cortical Microcircuits (BKC)
- K. G. Jebsen Centre for Alzheimer's Disease (JCA)

The Kavli Institute is an interdisciplinary village of experts with the common desire to understand how complex information is encoded in high-level neural networks and how complex behaviours arise from these codes and systems.

The institute staff is organized in eight work units: Seven research groups with associated teams of scientists, students and supporting staff under the leadership of eight principal investigators, and one central support group with technical, veterinary, and administrative staff under the leadership of an administrative director and a senior veterinary.

The department is responsible for an international Master's degree programme in Neuroscience, and has joint responsibility for the PhD programme in Medicine and Health Sciences at NTNU, and The Norwegian Research School in Neuroscience funded by the Research Council of Norway.

The Kavli Institute for Systems Neuroscience is a Centre of Excellence (CoE) since 2002, a Kavli Foundation Institute since 2007, a department at the Faculty of Medicine and Health Sciences at Norwegian University of Science and Technology (NTNU) since 2017, and a K. G. Jebsen Centre since 2020.

Scientific Director Edvard Moser leads the Kavli Foundation-supported activity of the institute, together with Scientific Co-Director May-Britt Moser and Managing Director Kay Gastinger.

CENTRE FOR NEURAL COMPUTATION (CNC) is a Centre of Excellence at the Research Council of Norway, aiming to extract the algorithms that give rise to an accessible mammalian cognitive function by taking advantage of the recent technological innovations for neural data recording and neural-circuit analysis.

How does the mammalian brain generate its own codes in the non-sensory cortices? This question marks the inception of understanding subjective experience. A path was opened in this terra incognita in 2005 when the Moser group discovered grid cells in the brain area called entorhinal cortex. Grid cells provide a metric for the brain's spatial mapping system. Since their matrix-like firing pattern is generated within the brain independently of specific sensory features, these cells provide unprecedented access to the principles for neural coding in higher-order association cortices. The centre uses these cells as a springboard for unravelling operational principles of the mammalian cortex.

Centre for Neural Computation has assembled a dedicated expert team to decipher the fundamental codes of the brain's circuits for space, time, memory, sensory integration, and action planning – the mechanisms by which signals from specialized networks of neurons are generated, transformed, stored and retrieved by local and global network operations.

Centre Leader May-Britt Moser heads the Centre for Neural Computation, together with Centre Co-Leader Edvard Moser and Managing Director Kay Gastinger.

EGIL AND PAULINE BRAATHEN AND FRED KAVLI CENTRE FOR CORTICAL MICROCIRCUITS (BKC) is a basic research centre studying the normal brain mechanisms that are affected by Alzheimer's disease.

The centre aims to understand the healthy workings of brain functions affected by Alzheimer disease. Special cells in the neural networks of entorhinal cortex are the very first to die in Alzheimer's disease, resulting in impaired brain functions.

The functional task of this brain area answers the hallmark questions of episodic memory - *when, where and what happened* - by generating our sense of space, our sense of time, and by organizing the content of our experiences and memories.

The Braathen-Kavli Centre studies will bring light to the inherent affordances of these cells and networks, to investigate why they are especially vulnerable to the disease.

The centre is realized by a donation from philanthropist Pauline Braathen, joined by her late husband Egil Braathen's nieces and nephew Mona Arnesen, Anita Lien, and Erik Ruud.

Centre Leader Edvard Moser heads the Egil and Pauline Braathen and Fred Kavli Centre for Cortical Microcircuits, together with Centre Co-Leader May-Britt Moser.

K. G. JEBSEN CENTRE FOR ALZHEIMER'S DISEASE (JCA) is a national research centre of interdisciplinary experts united in the common goal of determining the onset of Alzheimer's and the early stages of disease development.

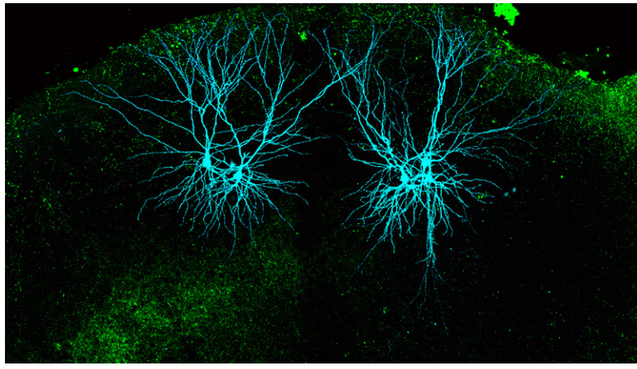
The vision of the Jebsen centre is *to translate Nobel Prize winning research from laboratory to patient*. To accomplish this, the Jebsen team of experts collaborate on a set of projects designed to bridge the gaps from basic science to clinical implementation. The centre activities span from basic research in rats and mice to clinical research in humans. Each step, from the lab to the patient, is quality assured with what is called translational research. Here, promising basic research results on healthy brains are translated to brains that have been affected by Alzheimer's disease, and the most significant findings from human brain disease are translated into animal models for testing before findings are reintroduced to humans.

Bringing together scientists across disciplines, the Jebsen Centre will establish a network of scientists to foster a healthy scientific discourse and to provide the society with quality assured scientific facts about Alzheimer's disease and the brain.

The centre is a large-scale collaboration that unites university and hospital and links them with prominent national and international partners. Jebsen researchers have access to state-of-the art technology from the NORBRAIN 2 and NORBRAIN 3 research infrastructure programmes.

The centre was made possible by a donation from the Foundation Stiftelsen Kristian Gerhard Jebsen of NOK 22.5 million. The Central Norway Regional Health Authority has contributed NOK 11.25 million and NTNU's Faculty of Medicine and Health Sciences has contributed NOK 5.63 million. St. Olavs Hospital and the National Association for Public Health, with its expertise and close contact with patients and relatives, will collaborate closely with the centre.

Centre Leader Edvard Moser heads the new K. G. Jebsen Centre for Alzheimer's Disease, together with Centre Co-Leader May-Britt Moser and Managing Director Kay Gastinger.



Courtesy of Eirik Stamland Nilssen / Kavli Institute for Systems Neuroscience.

Highlights

HIGH IMPACT RESEARCH

Moser Group researchers discovered a new type of principal neuron called *object-vector cell* that is fundamental to our brain's navigation system. While grid cells map and measure open space, object-vector cells measure space relative to the objects and landmarks that occupy it. The object-vector cells respond to any object that the animal takes notice of. Each cell fires when the animal is at a certain distance and direction to an object. In combination, the population of object-vector cells informs the animal about its distance and direction relative to all objects in the animal's environment. Vector codes can be applied to map where the animal is with any object as a reference. The object-vector cells were discovered in the brain's medial entorhinal cortex.

Another important discovery by **Moser Group** researchers is that grid cells maintain their activity structure when animals are sleeping. They found that grid cells that are active together when animals wander around in an open box, remain active together during sleep, and grid cells that are not active at the same time in the awake state are not active at the same time during sleep. This implies that the grid cell network maintains its activity structure in the absence of sensory inputs, and that the grid pattern may be a result of intrinsic network processes in the brain's navigation system.

Tracing neural highways, **Witter Group** researchers identified a *multisensory hub in the brain's lateral entorhinal cortex.* They discovered that this part of the brain receives and combines a wide array of information about our environment from other parts of the brain. This multisensory hub in the brain is damaged in early stages of Alzheimer's disease, which may explain the strong memory disturbance seen in such patients. The discovery demands a rewrite of long-standing ideas about how this brain region is wired up.

Kentros Group researchers discovered a means to make cell-specific tools that allow scientists to monitor and manipulate neural activity in targeted neural cell types and areas of the brain. The group used special genetic codes that regulate gene transcription, to look for genetic sequences that are unique for particular areas and cell types in the brain. They then combined these uniquely active enhancers with selected promoters to create cell-specific transgenic model organisms and viral vectors. This approach was called Enhancer-Driven Gene Expression (EDGE).

HIGH IMPACT PUBLICATIONS

1. **Høydal et al (2019). Object-vector coding in the medial entorhinal cortex. Nature**

2. **Gardner et al (2019). Correlation structure of grid cells is preserved during sleep. Nature Neuroscience**

3. **Doan et al (2019). Convergent projections from perirhinal and postrhinal cortices suggest a multi-sensory nature of lateral, but not medial, entorhinal cortex. Cell Rep**

Diaz Verdugo et al (2019). Glia-neuron interactions underlie state transitions to generalized seizures. *Nature Communications*

Kermen et al (2019). Investigating olfactory behaviors in adult zebrafish. *BioRxiv*

Fore et al (2019). Functional properties of habenular neurons are determined by developmental stage and sequential neurogenesis. *BioRxiv*

Olstad et al (2019). Ciliary Beating Compartmentalizes Cerebrospinal Fluid Flow in the Brain and Regulates Ventricular Development. *ScienceDirect, Current Biology*

Kaplan et al (2019). Entorhinal transformations in abstract frames of reference. *PLoS Biology*

Bellmund et al (2019). Mapping sequence structure in the human lateral entorhinal cortex. *eLife*

Bellmund et al (2020). Deforming the metric of cognitive maps distorts memory. *Nature Human Behaviour (online 2019)*

INTERNATIONAL CONFERENCES ORGANIZED

Menno Witter and Clifford Kentros
International summer school Molecular Genetic Tools for the Study of Neural circuits

Jonathan Whitlock
Organized "Generative Brain Symposium" at Kavli Institute in December

PRIZES, HONOURS, AWARDS AND COMITTEES

Menno Witter
Chair of the international evaluation committee for the Donders Institute, Nijmegen, The Netherlands (2019-2020)
Member of the international selection committee Bial Award in Biomedicine 2019

Raphael Kaplan
Association for Psychological Science Rising Star Award

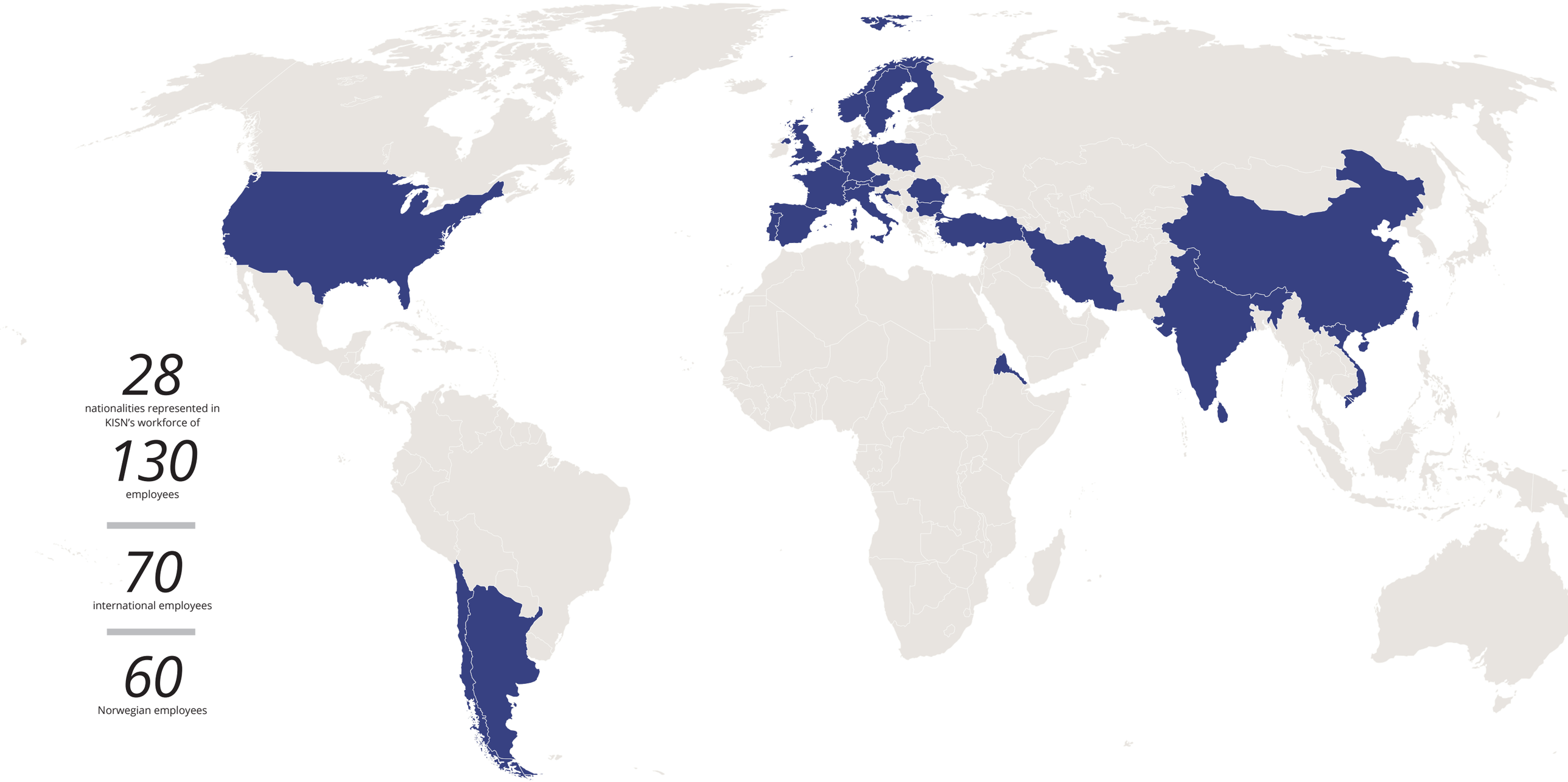
Jonathan Whitlock
Human Frontiers in Science Program (HFSP) review committee

PHD DEFENCES CARRIED OUT AT KISN IN 2019

Karoline Hovde (f), Tuce Tombaz (f), Bente Jacobsen (f), Benjamin Richard Kanter (m), Bartul Mimica (m), Thanh Pierre Doan (m), and Eirik Stamland Nilssen (m).

There are currently 26 active PhD candidates and 13 postdocs at KISN.

Facts



28
nationalities represented in KISN's workforce of

130
employees

70
international employees

60
Norwegian employees

Annual accounts

INCOME	
Norwegian Research Council: Centre of Excellence	17 500 000
Norwegian Research Council: Other	66 776 000*
International funding	12 520 000
Other public/private	11 219 000
Norwegian University of Science and Technology	56 350 000
TOTAL INCOME	**164 365 000**

EXPENSES	
Payroll and indirect expenses	78 239 000
Equipment	55 449 000*
Other operating expenses	30 677 000
TOTAL EXPENSES	**164 365 000**

* NORBRAIN 2 - Norwegian Brain Initiative: a large-scale infrastructure for the 21st century neuroscience.

SOURCES OF INCOME

* NORBRAIN 2 - Norwegian Brain Initiative: a large-scale infrastructure for the 21st century neuroscience.
NOK 14 million are allocated for NTNU-internal activities (master's programme et cetera). These funds are included in the figure "Sources of income", but not in the Annual accounts.

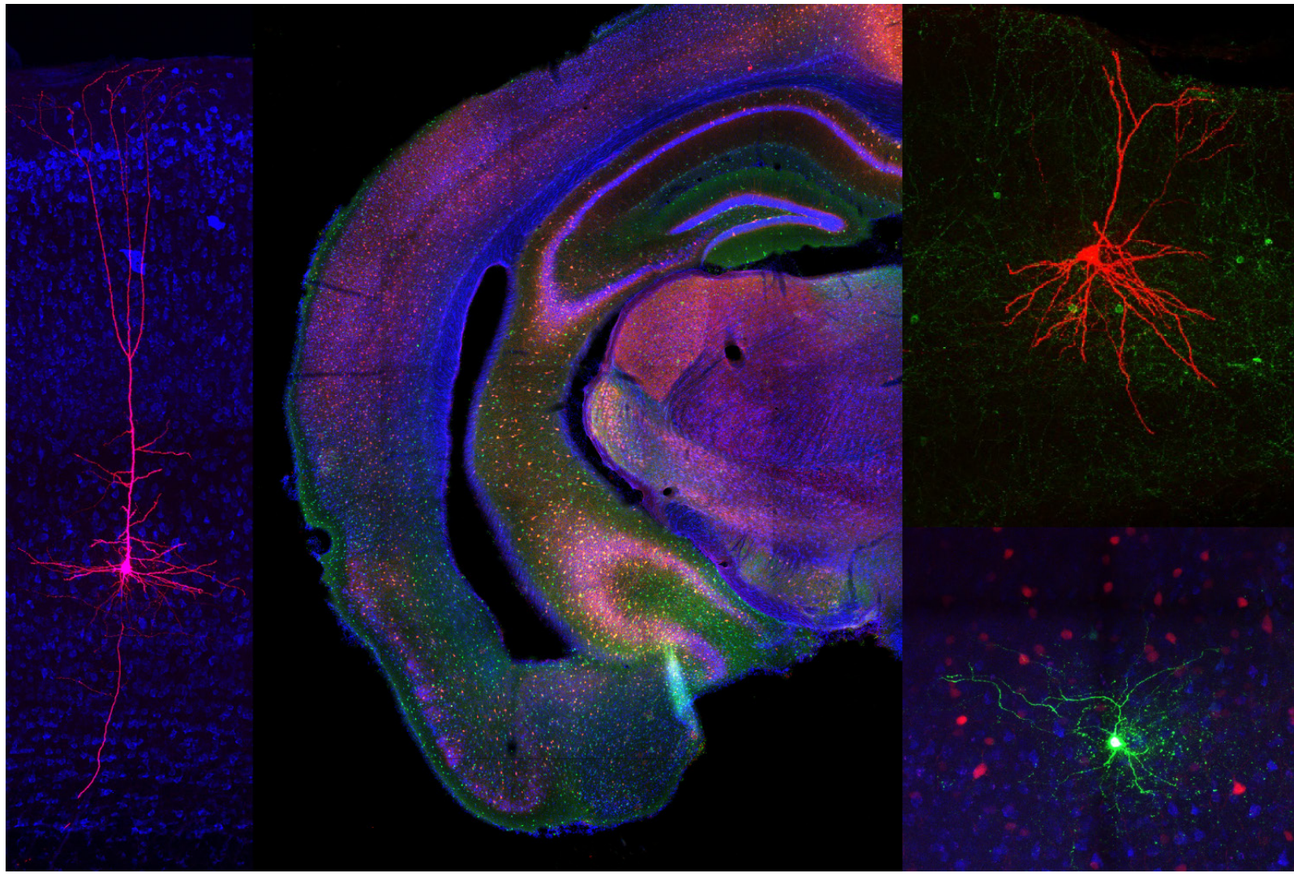
FINANCIAL STATEMENT

2019 was a year of transition for externally funded activities at the Kavli Institute. A number of projects were finalized, reducing the institutes total external funds to NOK 61 million, Centre of Excellence included. The major investment in a 7-tesla magnetic resonance brain-imaging machine financed by The Research Council of Norway, did however contribute to an overall increase of the budget in 2019.

The prospects for 2020 are optimistic, with several successful project applications scheduled to start this year. Additionally, The Ministry of Education and Research increased the basic contribution to the institute by NOK 12 million, to a total of NOK 28 million per annum.

If we didn't post about it, it didn't happen

Stay updated on the latest research news and events at KISN by following us on selected channels:



Courtesy of Maximiliano Nigro / Kavli Institute for Systems Neuroscience

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COVER IMAGE:
1050 entorhinal cortex cells including grid cells recorded simultaneously with new neuropixel probes. Each plot shows a cell's activity rate as a function of the animal's location.
Richard Gardner / Kavli Institute for Systems Neuroscience

LAYOUT AND PRINT:
Skipnes kommunikasjon AS

DOWNLOAD:
www.ntnu.edu/kavli/outreach

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EGIL AND PAULINE BRAATHEN AND FRED KAVLI CENTRE FOR CORTICAL MICROCIRCUITS

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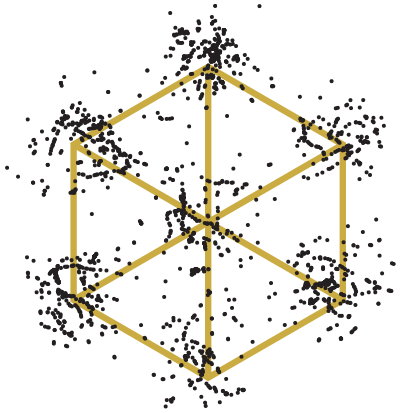

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