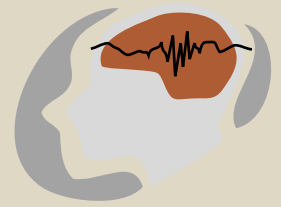


Annual Report 2008

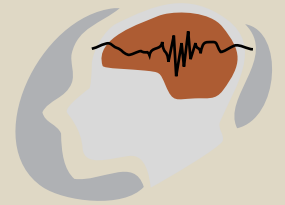
Kavli Institute for
Systems Neuroscience
and
Centre for the
Biology of Memory





The people at KI/CBM in front of the lab. (Photo: Hege Tunstad, KI/CBM)

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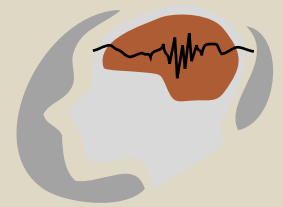
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Memory research in the media

It is important for KI/CBM researchers to share their knowledge and findings with the general public. Learning, memory and spatial navigation are critical throughout life, and explaining how the brain works is consequently of great interest.

KI/CBM researchers have shared their work with the general public in more than 200 articles in the popular media, such as a seven-page spread on Norwegian brain research in the weekly *A-Magasinet*, and on several TV programmes, including the MEMO school on the weekly science show, *Schrödingers Cat*, produced by the Norwegian Broadcasting Corporation (NRK). KI/CBM is also regularly visited by school classes and students, and since 2008 has arranged an annual public lecture on brain science, the Kavli Lecture.

The brain's complex communication system



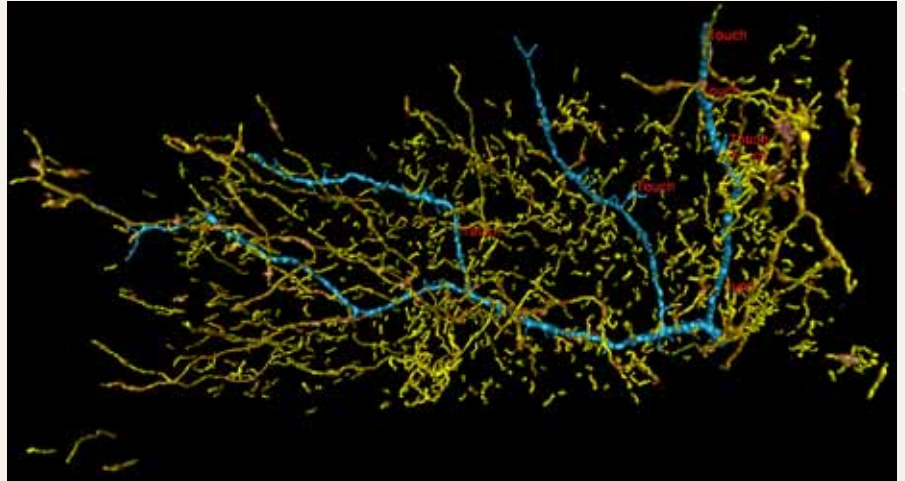
There are many striking similarities between the brain and a modern computer. But the brain is far more flexible than any piece of advanced technology.

One of the similarities between the brain and a computer is that both receive and process information, and both store information that can be retrieved later. The hippocampus in the brain can be compared with the internal memory of the computer in the sense that it receives sensory impressions, processes them and sends them on in the form of electrical signals to different parts of the cerebral cortex. The cerebral cortex can in some ways be compared to the computer's hard disk because it stores information on a long-term basis. The comparison is not entirely accurate, however, because the hippocampus can also store memories for relatively long periods of time.

A computer processes and stores information using the binary system, where every piece of information is converted into strings consisting of the two numbers "0" and "1". The brain performs in a similar way, because information is transmitted through action potentials that also have only two values, "on" and "off".

The flexible brain

"There are more similarities between the brain and a computer, but one of the main differences is that the brain is much more flexible. Computers usually perform their calculations according to fixed rules and procedures, and the wiring between the different elements of the computer is also fixed. In comparison, the individual neurons in the brain are able to respond far more flexibly to an incoming signal (an action potential). Depending on the situation, they can either transmit a new signal to another cell, stop the signal because they are inhibited, or use their own signalling frequency. Computers do not normally have this attribute unless they are specially programmed for it. In other words, the brain is more subtle in the way it deals with information", says Professor Witter.



Understanding the architecture of networks in the brain is an important requirement for understanding function. Some of the recipient components of a neuron (blue) and their inputs (yellow). Picture courtesy of Natalia Kononenko.

Another important difference is that the brain can rewire itself. "Individual neurons or parts of the brain can change their number of connections to other neurons or alter the efficiency of their connectivity. In some cases, for example if the brain is injured, the damage can be partially compensated for by rerouting information. Normal computers can't do this sort of thing", explains Witter.

Furthermore, the brain does not wear out or become out of date after a few years. This is because information is physically stored in the synapses, which are the contact points between brain cells. When the brain is used regularly, more synapses are formed, a process that can be compared to installing a larger hard disk in a computer.

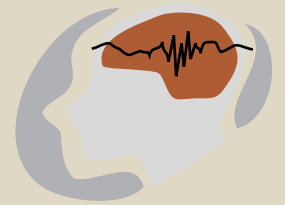
There are even more parallels between the brain and advanced technological equipment. "The entorhinal cortex as a whole can be compared to the Global Positioning System (GPS) you may have in your car. This navigation system not only works well in Trondheim, it would still work if you drove to Paris. All the GPS does is to connect with several different satellites that report back 'You are now in Paris'. But the brain has its own satellites, which are located in the hippocampus. The hippocampus tells the entorhinal cortex not only that you are in Paris, but also that you are now at a specific place in Paris. The goal of our research is to

discover in detail how these systems work together to build a complete navigational system", Witter adds.

"Many of the Trondheim researchers are investigating how the different networks in the brain communicate with each other. Just as a radio transmitter can send signals of different frequencies, so the brain seems to use certain frequencies to transmit information to a particular part and others for transmitting information to a different part. However, while radio signals have a very high frequency, the frequency of brain signals is low. Among the most common frequencies for brains are the theta wave, which varies between 6 and 12 Hz, and gamma waves, of about 30-100 Hz. We are beginning to understand why the brain uses such frequencies, and how they can be used to control communication between different parts of the brain", explains Witter.

Rat navigation helps unlock the brain's secrets

The ultimate goal of KI/CBM is to understand the biology of memory, and it was decided at an early stage that the research would concentrate on the navigation process in the rat. This is an area of research that provides good practical opportunities for experimenting with memory, partly because the parts of the rat's brain involved in navigation and memory are very similar to the corresponding parts of the human brain.



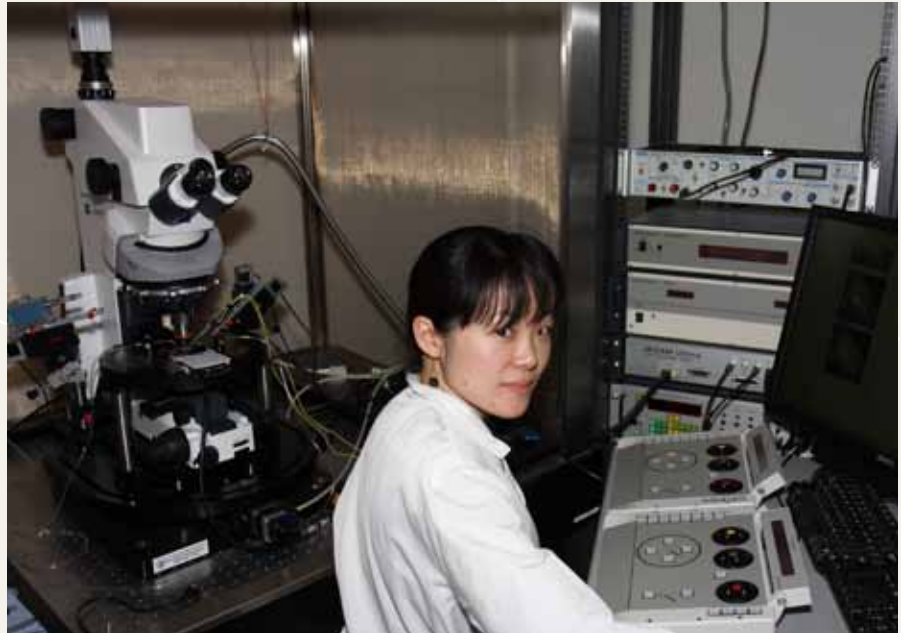
Since its establishment in 2002, KI/CBM has produced a series of sensational findings. In its first year of operation, researchers found that direct inputs from the entorhinal cortex to the hippocampus are responsible for spatial orientation. In 2004, they showed that the entorhinal cortex contains an accurate spatial map of the animal's environment. In 2005, researchers discovered grid cells in the entorhinal cortex, which form a map with coordinates that are comparable to those on a map you can buy in a bookshop. The following year, researchers found cells that function like a compass and a speedometer. More recent research has also uncovered border cells and large place cells (see pages 5 and 6 below).

Professor Witter joined the CBM in 2007 because he considered it one of the world's best institutes for research on the hippocampus and the parahippocampus and their relationships with other parts of the brain as an essential basis for learning and memory. He heads the Neuroanatomy Group, which is investigating the links between the structure and functions of the brain. "On the basis of the brain's architecture, we try to make predictions about its function and vice versa. You can't really understand how the brain functions without understanding the architecture", Witter says.

Networks enable brain function

While the research groups headed by May-Britt and Edvard Moser record electrical signals from neurons in the brain of rats that run around in the laboratory, Witter's group records signals from slices of living brain tissue. This makes it possible to investigate how the neurons relay information to the next link in the processing chain. "Our real focus is on the network level. This insight into the importance of networks has really evolved over the last 10 years or so. Brains don't function by virtue of their isolated neurons. They work because they have networks, and these networks can form larger structures", Witter says.

Thus the brain is in some ways comparable to a computer, in others to a satellite navigation system, and in still other ways to a radio communications system. Our advances in



Noriko Koganezawa in her laboratory where she does optical recordings of electrical activity in slices of the entorhinal cortex. (Photo: Raymond Skjerpeng, KI/CBM)

technology have given us a vocabulary that makes it easier to describe the brain and memory processes.

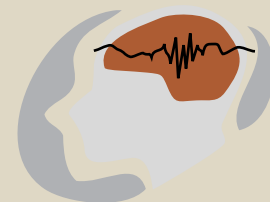
"None of these comparisons are perfect, but they certainly make it easier to explain and understand the workings of the brain", Witter concludes.

The seats of memory and of the sense of place in the brain

The entorhinal cortex is an area in the cerebral cortex that is located in the medial part of the temporal lobe, and plays a vital role in memory and the sense of place. Sensory information of all kinds is transmitted to the entorhinal cortex, which feeds it into the hippocampus. Here associations are formed between different items of information, resulting in episodic memories.

The hippocampus is also located in the medial temporal lobe and also plays a major role in memory and spatial orientation. It serves as a provisional storage centre for memories that are later stored in other parts of the cerebral cortex. If the hippocampus is damaged, for example in Alzheimer's disease, we lose our ability to remember new life episodes, even though we can still recall past memories in an almost normal way.

Towards a new understanding of the cognitive functioning of the brain



In 2005, researchers at the CBM in Trondheim showed for the first time that the rat brain has its own universal map for encoding self-position in any environment. The discovery, reported in *Nature*¹, has opened up new opportunities to investigate the cognitive functioning of the brain.

The brain mapping system, which is probably also found in the human brain and that of other mammals, is located in the entorhinal cortex, where the newly discovered grid cells were found.

“Previous studies had shown how the rat brain registers sensory impressions like contours or lines that it receives through the eyes, but when we discovered the grid cells we realized for the first time how neurons right inside the cortex create new codes to interpret incoming sensory signals. In other words, we began to see how networks of brain cells compute, which brings us right into what we call cognitive processes”, says Professor Edvard Moser, who is director of KI/CBM together with May-Britt Moser. The discovery of grid cells has created a new area of research at KI/CBM. “We’re hoping to learn more about the neural basis of all mental activities. We can start by assuming that the brain often follows the same principles for several different functions. So if we can find the explanation for one phenomenon, we’ll probably also discover a lot about other brain phenomena. Our focus for the next few years will be on research that can help us understand the mechanistic basis of cognitive functioning,” Moser explains.

Computational neuroscience and molecular biology

The Mosers have already begun planning for the years after 2012, when the centre of excellence grant from the Research Council of Norway comes to an end. The researchers will continue to pursue their original goal, to understand the biological basis of memory, and will concentrate on two scientific fields.

1 Hafting, T., Fyhn, M., Molden, S., Moser, M.-B., and Moser, E.I. (2005). Microstructure of a spatial map in the entorhinal cortex. *Nature*, 436, 801-806.



KI/CBM directors Edvard and May-Britt Moser have already planned the direction for the Institute’s research after 2012. (Photo: Geir Mogen/DMF)

“One of the fields is computational neuroscience, in which we use computers to generate realistic models of brain networks. These make it possible to test hypotheses about the brain’s cognitive processes by means of biological experiments. The method reduces the need for animal experimentation by showing what is possible and not possible within a given brain network,” says Moser. The other science is molecular biology, which will be used to investigate neural net-

works. “Here we use genetically modified, or ‘harmless’, viruses to turn genes on and off in specific types of cells. For example, if we believe that six different cell types in a neural network are involved in a particular brain function, we can inject a tailored virus to turn off all the cells in one group. It’s a bit like turning off the switch for those cells in order to find out what their functions are”, explains Moser.

The way ahead

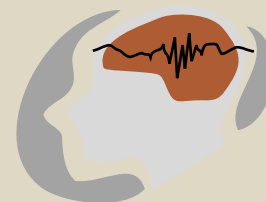
KI/CBM has already begun using these two methods, and through its agreement with the Kavli Foundation, NTNU has committed itself to establishing two new professorships, one in computational neuroscience and the other in molecular neuroscience with a focus on systems biology. International research communities agree on the importance of these two fields for the advancement of neuroscience.

10th *Nature/Science* article

In May 2008, KI/CBM researchers published their 10th original article in *Nature* or *Science*. The researchers (first authors were Torkel Hafting, Marianne Fyhn, and Tora Bonnevie) demonstrated theta phase precession in grid cells in layer II of the medial entorhinal cortex.

The findings show that this temporal code can emerge in grid cells independently of the hippocampus.

New type of brain cells key in spatial orientation



May-Britt Moser and Trygve Solstad are excited about finding a new type of brain cells in rats. (Photo: Tove Gravdal/Morgenbladet)

The discovery by KI/CBM researchers of a new type of brain cell that registers borders and barriers caused scientific excitement worldwide when it was published in the 18 December 2008 issue of the American journal *Science*¹.

The Trondheim researchers had previously published a number of pioneering studies reporting three other types of brain cells that are activated in rats, and probably in humans, as an individual moves through the physical environment. Thus by the beginning of 2008 the researchers knew that the brain contains specific networks of place cells, head-direction cells and grid cells respectively, and that these cells work together to construct an internal map that is used for spatial orientation in a known and unknown environment. In 2008 they found a missing element of the map, cells that also play a vital role in spatial orientation and the sense of place: the border cells.



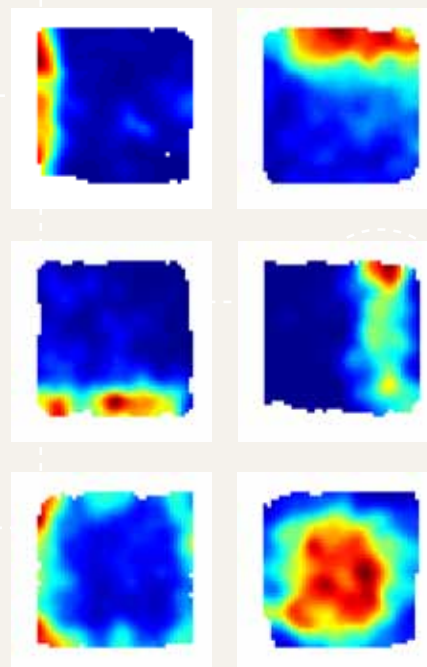
The search for border cells

Previous research had shown that rats orientate themselves in space through a process by which three different cell networks that register specific points in the physical environment, the direction in which the rat is moving, and the rat's position in relation to a grid drawn by other specialised cells. Together the networks form what can be called "the brain's GPS system". But a GPS system needs to be calibrated in relation to its surroundings. It requires supplementary information if it is to be a useful navigation instrument, and the researchers believed that there must also be another type of brain cells.

"We deduced that there must be cells whose task is to identify borders. Neil Burgess at University College London had developed a mathematical model pointing in that direction," explains PhD student Trygve Solstad. After a six-month search Solstad and colleagues found what they were looking for. "We've now discovered that there are in fact special cells that register the transition from one environment to another. These border cells fire electrical signals when the rat approaches a physical border like a wall, a fence or a drop. At first we thought these border cells were located in a specific layer of the entorhinal cortex, but it turns out that they occur in all layers of the medial section of the entorhinal cortex, and are often intermingled with head-direction cells and grid cells," explains Solstad.

What next?

The article in *Science* attracted international attention, and was reported in the news section of the journal *Nature*. The neurosci-



Pattern of electrical activity recorded in six entorhinal cells while the rat explored a square arena. The pattern of activity shows that the cells respond to borders.

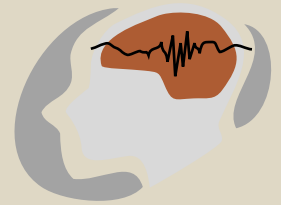
entist Jeffrey Taube at Dartmouth College in the US acknowledged that the neuroscience community is becoming very interested in the findings from Trondheim. "My first impression [when I read this paper] was 'What will this group find next?'" said Taube to *Nature*.

Solstad is not sure whether border cells, head-direction cells, grid cells and place cells are fundamentally different types of cells, or whether the same type of cell has developed different functions. "We can't see any difference between these cells without examining their functions. Their anatomy is the same and they send the same signals. We hope to discover more about this by means of the molecular biological techniques that are being developed here at the centre," comments Solstad.

Specific brain cells in exploring rats will recognize that the rat is approaching a border (Photo: Raymond Skjerpeng, KI/CBM)

¹ "Representation of Geometric Borders in the Entorhinal Cortex", by Trygve Solstad, Charlotte N. Boccara, Emilio Kropff, May-Britt Moser and Edvard I. Moser

The brain's built-in scales



Researchers at KI/CBM have previously shown that place cells in the hippocampus of the rat brain are only activated when the animal passes specific points in its surroundings. In 2008 they discovered that these cells can operate at scales varying from about 50 centimetres to 10 metres.

The findings reported in Kirsten Brun Kjelstrup's doctoral thesis were published in the 4 July 2008 issue of *Science*¹. Kjelstrup and colleagues had shown that place cells had well-defined place fields, or pixel size, to use an expression from photography. At the ventral pole of the hippocampus the scale of spatial representation at which the place cells fire is around 10 metres, with a steady decrease down to 50 centimetres at the dorsal pole. The place cells receive information from the senses, especially vision, and from body movements. In rats the sense of smell is also important.

"You could say that the hippocampus has an inbuilt map with a number of different scales. It's as if you compared a road atlas with an orienteering map: both maps are appropriate for their purpose, but they cannot serve as substitutes for one another," explains Kjelstrup.

Tempted by delicacies

"We arrived at these results by recording electrical signals from the place cells while rats ran back and forth on an 18-metre-long linear track with delicacies at each end. The place cells in the ventral part of the hippocampus fired in fields of up to 10 metres, while those in the dorsal part only fired in fields as small as 50 centimetres. These cells are all pyramidal cells, but we found

1 "Finite Scales of Spatial Representation in the Hippocampus", by K.B. Kjelstrup, T. Solstad, V.H. Brun, T. Hafting, S. Leutgeb, M.P. Witter, E.I. Moser, and M-B. Moser at the Kavli Institute for Systems Neuroscience and the Centre for the Biology of Memory, Norwegian University of Science and Technology, Trondheim, Norway; M.P. Witter at the VU University Medical Center in Amsterdam, the Netherlands.



PhD Kirsten Kjelstrup, and colleagues discovered that the hippocampus has an inbuilt map with a number of different scales.

that they had different electrophysiological properties," Kjelstrup says. There was no room in the laboratory for a longer track, but the researchers believe that there is a limit to the size of the field the place cells can cover. "We think the upper limit is about 10 metres in rats. We have now found a complete navigation system in



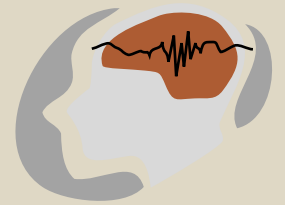
The 18-metre track. There was no room in the laboratory for a longer track, but the researchers believe that there is a limit to the size of the field the place cells can cover.

the rat brain and a similar system has been found in the temporal lobe of the human brain. You need a system that can navigate at the one-metre level in a small room, but you need a larger scale when you're going shopping. But we don't think there are any place cells that cover even longer distances, like those covered by a train journey," explains Kjelstrup. Earlier studies at KI/CBM have shown that the grid cells in the entorhinal cortex also have spatial representation scales that increase from the dorsal to the ventral poles, and that they communicate with the hippocampus.

Cranks, pulleys and wires

These unique research results are due in part to an extremely creative experimental protocol. Thin electrodes were implanted in the brain close to the neurons concerned, and neural activity was recorded by means of cables up to 10 metres long that hung down from the ceiling and were linked to a PC. The researchers had to build a whole system of cranks, pulleys and wires so that the cables could keep pace with the rats for the whole length of the track. A laser was used to measure position and speed.

ERC and FP7 grants



The Spacebrain project: a comprehensive understanding of the brain

In 2008 seven universities and research organizations in Europe and Israel started the Spacebrain project with the goal of developing a more comprehensive understanding of the brain. The project is being coordinated by Professor Edvard Moser at the KI /CBM and is funded by the EU Seventh Framework Programme (FP7) for research.

As a result of the major worldwide efforts to understand the fundamental operations of the brain over the past 10-20 years, significant advances have been made at almost every level of analysis. "But in spite of the expansive growth of the field, our understanding of brain functions is still largely confined to the individual levels of analysis. We can explain in detail how a spike is propagated through an axon or a dendrite, or describe which particular brain regions are recruited during a memory retrieval task, but we only have a limited mechanistic understanding of how operations at the microscopic levels lead to more complex mental functions," explains Moser.

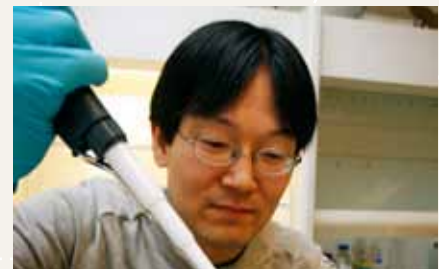
To explain how complex mental functions originate from electrical and chemical processes in brain cells, and how these functions can disintegrate during disease, a comprehensive and integrated cross-level analysis is needed of how large numbers of heterogeneous synapses and neurons in distinct brain systems interact during behaviour.

"The aim of the Spacebrain project is to discover the principles of microcircuit computation in the spatial representation system of rodents. For this we are using a powerful combination of novel computational, electrophysiological, optical and molecular research tools that have never before been applied to the analysis of brain circuitry. Neuroscience is now at a stage where these comprehensive challenges can be addressed," says Moser.

In addition to KI/CBM, the following institutes are involved: Axona Ltd (the UK), the International School for Advanced Studies (Italy), University College London (the UK), the University of Zürich (Switzerland), Universitätsklinikum Heidelberg (Germany) and the Weizmann Institute (Israel).

European Research Council grant awards

The European Research Council (ERC) awarded an Advanced Investigator Grant to Professor Edvard Moser, and a five-year Starting Grant to group leader Ayumu Tashiro in 2008.



Ayumu Tashiro received a five-year grant from the European Research Council in recognition of his work.

(Photo: Gorm Kallestad/Scanpix)

This year marks the first time the ERC has awarded the Advanced Investigator Grant. The prestigious award funds frontier research under the Ideas Programme of the EU's Seventh Framework Programme, which created the ERC. The grant requires that the project be "highly ambitious, pioneering and unconventional" and that its research leader, or Principal Investigator, be an "exceptional research leader" in or associated with the European research community. The grant is for EUR 2.5 million over five years.

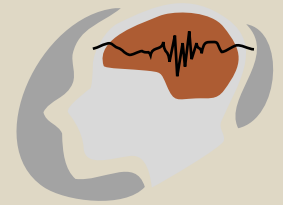
Moser's project will explore how complex mental phenomena such as memory, spatial location and decision-making arise from interaction between the millions of neurons in the brain. Moser's Advanced Investigator Grant is one of two given to institutions in Norway

The ERC's five-year grant to Tashiro totals almost EUR 2 million and will enable him to expand and upgrade his virus lab, where he will combine multi-unit recording and behavioural analysis with virus-mediated, cell-type-specific genetic manipulation of neuronal activity. Tashiro was the only researcher in Norway to receive a Starting Grant in 2008. Tashiro is the McDonnell Foundation Research Fellow at KI/CBM.



Participants of the SPACEBRAIN kick-off meeting at Kongsvoll Fjeldstue
(Photo: Knut J. Nyhus)

Kavli happenings



The Kavli Prize was awarded for the first time in Oslo on September 9, opening a week of red carpet events. The week of September 9 -12 was celebrated as Kavli Week in Trondheim, with prize lectures, the annual Kavli Lecture, a formal dinner and the Kavli Inaugural Symposium.

First Kavli Awards

Crown Prince Haakon of Norway presented the Kavli Prizes for international research to seven of the world's most prominent scientists in astrophysics, nanoscience and neuroscience. Two of the neuroscience honourees, Sten Grillner and Pasko Rakic, gave their official lectures at the Norwegian University of Science and Technology in Trondheim, while Tom Jessell presented his lecture in Oslo.



Fred Kavli and Eric Kandel enjoyed the festivities during the Kavli Week.

The Kavli Prize winners and Fred Kavli were treated to a festive dinner at the Archbishop's Palace, hosted by Sør-Trøndelag County, the city of Trondheim, and NTNU.

Kavli Inaugural Symposium

The Kavli Prize winners and other giants in the field of neuroscience shared their thoughts and findings in a series of lectures at several universities and at the Kavli Inaugural Symposium. Among the speakers were Richard Morris, Thomas Jessell, Fred Gage, Anders Bjørklund, Wolf Singer, György Buzsáki and Laura Colgin.

Annual Kavli Lecture

Nobel Laureate Eric Kandel gave the annual Kavli Lecture at the Student Society in Trondheim. The auditorium at the Student Society was packed with more than 750 students and others, eager to learn more about how the mind works. Kandel's lecture, "We are what we remember - memory and the biological basis of individuality", received a standing ovation, as well as a two-page spread in the regional newspaper the fol-

lowing morning. Kandel, who is Director of the Kavli Institute for Brain Sciences at Columbia University, USA, received the Nobel Prize for physiology or medicine together with Arvid Carlsson and Paul Greengard in 2000.

The Kavli Lecture was introduced by Fred Kavli, who shared his memories of parties at the Student Society while he himself was a student in Trondheim six decades ago.

Red carpet week

"This was a week of red carpet events," says Director Edvard Moser at KI/CBM. "We wanted to show the citizens of Trondheim what the ideas behind research in neuroscience are all about, so we arranged for Eric Kandel to give his public lecture in the large auditorium at the Student Society. We were pleased to see that Nobel Laureate Kandel was received almost like a rock star. The Kavli prize awards in Oslo were a worthy tribute to some of the greatest researchers in this field, and the lecturers have all presented important aspects of neuroscience research and discoveries," says KI/CBM's director, Edvard Moser.

"My aim is to support scientific work on the cutting edge of research", said Fred Kavli in his acceptance speech at the Trondheim award ceremony. (Photo: Thor Nielsen/NTNU Info).

Fred Kavli gets honorary doctorate

On 23 May 2008 the philanthropist Fred Kavli was given a doctorate honoris causa, or honorary doctorate, by the Norwegian University of Science and Technology, in recognition of his outstanding work for the benefit and advancement of science and research.

Kavli was recognized for his fervent dedication to and profound knowledge of science and research in many different fields. Kavli has been dubbed 'the next Nobel' by *Time Magazine* because of his great contribution to scientific success, understanding and cooperation throughout the world.

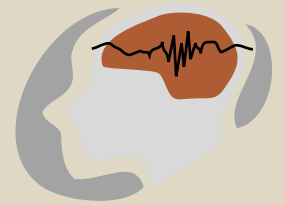
Kavli received an engineering degree in technical physics in 1955 from the then Norwegian Institute of Technology, now part of the Norwegian University of Science and Technology. The University thus honoured one of its most successful former students.

In 1958 Kavli founded the Kavlico Corporation in Los Angeles, California. The company soon became a leading supplier of sensors to a number of industries.

After selling the Kavlico Corporation, he set up the Kavli Foundation in 2000. The foundation supports scientific research at leading universities in several different countries. There are currently 15 Kavli Institutes, of which the Centre for the Biology of Memory was the first to be established in Norway when it was named the Kavli Institute for Systems Neuroscience in 2007.



Prizes



Spatial positioning research wins the Fernström Prize



The Dean of the Medical Faculty of Lund University, Bo Ahren, May-Britt Moser, the Chairwoman of the Fernström Foundation, Elisabeth Edholm, and Edvard Moser.
(Photo: Fernström Foundation)

The Eric K. Fernström Foundation has selected Professors May-Britt and Edvard Moser as the winners of the 2008 Fernström Prize.

The Mosers were recognised for their “groundbreaking research on the mechanisms in the brain that determine our spatial position”.

The Swedish businessman Eric K. Fernström (1901-1985) founded the highly successful Fernström shipping company and was CEO of A.K. Fernströms Granitindustrier, which supplied the stone for the façade of the Empire State Building in New York and the U.S. Marine Corps War Memorial in Washington D.C. In 1978 he established the Eric K. Fernström Foundation for the promotion of scientific research in medicine. Prizes are awarded to particularly promising researchers in the medical sciences.

The Fernström Prize is awarded every year to a medical researcher from one of the Nordic countries.

Tashiro wins Peter and Patricia Gruber International Research Award in neuroscience

Kavli Institute/ERC research fellow Ayumu Tashiro has won the Peter and Patricia Gruber International Research Award in Neuroscience. The Foundation's Young Scientist Awards, selected in partnership with preeminent science organisations, aim to recognize brilliant early career scientists from around the world. The prize includes USD 25 000, and was awarded at a ceremony during the annual meeting of the Society for Neuroscience.



Distinguishing between similar memories: the brain's secrets discovered

KI/CBM research scientist Jill Leutgeb was awarded the Royal Norwegian Society of Sciences and Letters 2008 Young Researcher Prize in the Natural Sciences for her work on the neuronal mechanisms of pattern separation.

Leutgeb received the prize for her research on the different roles played by each of the hippocampal subregions during spatial memory formation and retrieval. Thanks to her findings, critical advances have been made in our understanding of how the brain is able to distinguish between our various memories.

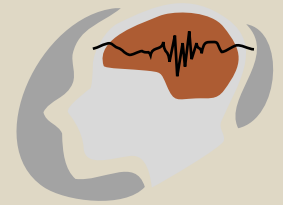
Leutgeb investigated the question of how the brain can distinguish between similar memories. She found that the brain solves the problem by exaggerating the differences between the external signals it receives in a process called pattern separation.

The theory that the brain's differential amplifier is to be found in a small area of the hippocampus called the gyrus dentatus was considerably strengthened by these findings. The work was published in *Science*, in an article by Leutgeb and her colleagues Stefan Leutgeb and Edvard and May-Britt Moser entitled “Pattern Separation in the Dentate Gyrus and CA3 of the Hippocampus”.

The prize, which is worth NOK 25 000, is funded by I.K. Lykkes Fond and was awarded to Leutgeb at a ceremony on 7 March 2008.

Jill Leutgeb receives the Young Researcher Prize from the Royal Norwegian Academy of Science and Letters.

Fridtjof Nansen Conference on ...



Leading brain researchers from all over the world met in Svalbard in June 2008 for the Fridtjof Nansen Conference on Neural Networks and Behaviour. At the end of the highly successful meeting, KI/CBM organisers Edvard and May-Britt Moser and Menno Witter received a standing ovation.

perhaps any other area. This development largely reflects the recent integration of theoretical and experimental neuroscience along with approaches from subdisciplines such as neuroanatomy, neurophysiology, molecular biology, behaviour, statistics and mathematics. The conference organisers felt that the emergence of a mechanistic understanding of memory in the networks of the cerebral cortex would benefit from

funding from the Norwegian Research Council

Fridtjof Nansen, neuroscientist

Although Fridtjof Nansen is best known both at home and abroad as a great polar explorer, he actually started his career as a biologist, and became intrigued early on by the central nervous system. While working at the Maritime Museum in Bergen he



Participants at the Nansen conference at 1 am on the third day (Photo: Raymond Skjerpeng, KI/CBM)



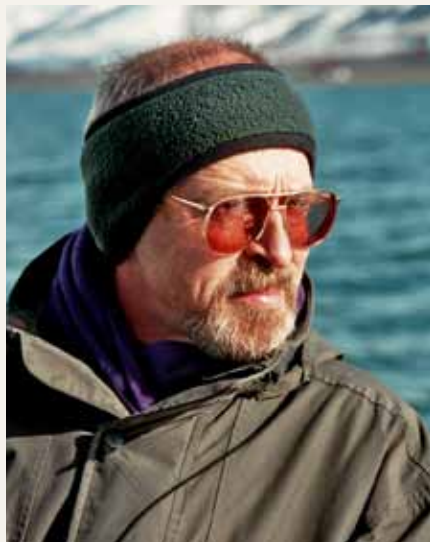
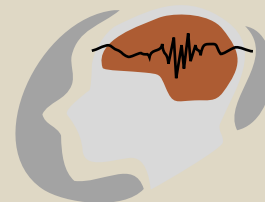
Participants at the Svalbard conference were impressed by both the scientific content and the unforgettable setting. (Photo: H. Hellebostad)

The background for the conference was the growing understanding among neuroscientists of how neurons and neuronal networks compute. Our knowledge of the neuronal computations underlying spatial representation and memory is maturing faster than in

close and creative interaction between leading neuroscientists with different conceptual and methodological approaches. The goal of the Fridtjof Nansen Conference on Neural Networks and Behaviour was thus to stimulate this interaction in an unforgettable place and context. The conference received partial

became deeply interested in the question of how nerve cells communicate, and acquired one of the most advanced microscopes of the time. The prevailing concept about the nervous system in Nansen's day was the reticular theory, which held that the nervous system essentially had no discrete elements. Under his new microscope, however, Nansen saw no continuity, only free nerve endings. The Golgi method for staining and studying nervous tissue was just becoming known, and so in February 1886 Nansen travelled to Italy to work with Golgi. After mastering the technique, he continued his exploration of the nervous system at the marine biological station in Naples, established by Dohrn. He was probably the first to apply the Golgi technique to lower vertebrates.





Menno P. Witter, KI/CBM. (Photo: B. Srebro)

Nansen's work developed along the same lines as that of his contemporaries, such as His and Forel, and his finding that nerve cells are enclosed by membranes, which implies that they are discontinuous, supported theirs. Nansen published these major contributions in English, in established international journals, but it was not until he translated them into Norwegian that he received his doctorate from the University of Oslo in 1887. Thus he was not only the first Norwegian (and in fact Scandinavian) neuroscientist, he was also one of the first proponents of the neuronal theory of the brain that prevails today.

The Svalbard experience

Svalbard is a unique experience. The archipelago is located in the Arctic Ocean and hosts the world's northernmost educational institution, the University Centre in Svalbard (UNIS). The average temperature during the summer is +6 °C, but may sink to 0° C. Polar bears roam the area, and anyone who wants to go exploring outside the small city of Longyearbyen is urged to hire a guide for protection from the bears.

The participants were very appreciative of the scientific content of the conference and



Alessandro Treves, SISSA
(Photo: H. Hellebostad)

found the Svalbard experience unforgettable. As Nobel Laureates Bert Sakmann from the Max Planck Institute of Neurobiology in Martinsried in Germany and Susumu Tonegawa from MIT in the US told a reporter from the Norwegian Broadcasting Corporation, Norway is on the leading edge of neuroscientific research, and the work of



Matt Wilson, MIT (Photo: B. Srebro)

the Kavli Institute in Trondheim is being followed all over the world.

There were many other positive comments offered during the summing-up on the last day. A few examples:

"If there was a single point of agreement among the critical participants, it was that the Svalbard meeting was the best ever gathering of hippo-minded individuals."

"I've never seen conference organizers get a standing ovation at the end of a meeting. This is a reflection both of gratitude for the meeting and of the status of your scientific achievements!"



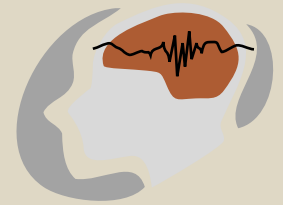
Yasushi Miyashita, University of Tokyo School of Medicine and Per Andersen, University of Oslo
(Photo: H. Hellebostad)

"Excellent talks, discussions and personal contacts with many new and old friends. And the boat cruise to Pyramid [a Soviet, later Russian, settlement in Svalbard] made a really unforgettable episodic impact, as perhaps you may have intended."



Conference participants hiking on Platåfjellet (Photo: Edvard Moser, KI/CBM)

Noble visitors



Nobel Laureate James D. Watson with a group of researchers at KI/CBM and reporters from the National Broadcasting Company. (Photo: Ingvill Warholm/NRK)

Nobel Laureate James D. Watson, who along with Francis Crick discovered the double-spiral structure of the DNA molecule and revolutionised genetics and medicine, has seen quite a few laboratories in the years since he made his world-shaking discovery in 1953. So when he told scientists at KI/CBM in June 2008 that he wanted to visit it because "I had heard this was one of the best labs in the world," they were delighted.

Watson (born 1928) was only 34 when he received the Nobel Prize in Physiology

or Medicine in 1962, together with Crick and Maurice Wilkins, who had done much of the groundwork that resulted in this remarkable discovery.

Watson continues to pursue his research at Cold Spring Harbor Laboratories on Long Island, New York, in addition to writing several bestselling books and lecturing in every part of the world. When he visited Trondheim in 2008, his June 3 lecture in the large auditorium of the Laboratoriebygget at St. Olav's Hospital was so popular that many

people had to be turned away. His lecture included advice for young scientists about how to live a scientific life if they had high ambitions. Afterwards he had to undergo a true test of fortitude, signing autographs and posters and posing with those who wanted to be photographed together with a world-famous Nobel Laureate.

Watson was also taken on a boat trip along the coast of Trøndelag, which included a barbeque on a small island off the Ørlandet peninsula. He was accompanied by research colleagues at KI/CBM and a team from the Norwegian Broadcasting Corporation, who wanted to film him for the popular science television serie, Schrödinger's Cat.

Watson's scientific career has been impressive and varied. After heading the Human Genome Project, an American-based project set up to map human genetic material, he went on to do cancer research, and in more recent years he has developed a particular interest in the brain. After hearing a lecture given by Professor Edvard Moser in the US, he invited himself to KI/CBM in Trondheim. "I am very impressed by the work being done here," said Watson after being shown around the Institute.

Research minister is highly impressed

Tora Aasland, the Norwegian Minister of Research and Higher Education, visited KI/CBM on 15 January, and was full of admiration for what she saw.

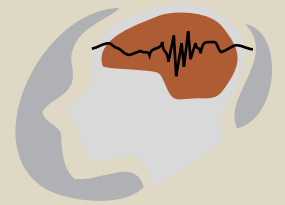
"I'm impressed by the level of research being done at the Centre. One of my main concerns as Minister of Research is to provide favourable conditions for the development of centres of excellence for research and to promote private funding of research, for example through a combination of private and government funding. Fred Kavli's financial contribution to the Centre for the Biology of Memory therefore fits in with the Government's thinking," said the Minister after her visit.

She added: "Good basic research like the work being done at this centre is a requirement for applied research and technological innovation, and the Government's research policy goals reflect this. I will be eagerly following the work of the Centre, and I'm glad to learn that the researchers here consider that making their results known to a broader public is an important part of their activity."



Research Minister Tora Aasland visited KI/CBM in January 2008. PhD-student Charlotte Boccara presented the lab's most important workers: the rats. (Photo: Haagen Waade KI/CBM)

Who's who at KI/CBM



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Faculty



Edvard I Moser
Professor and Director



May-Britt Moser
Professor and Co-Director



Menno P. Witter
Professor



Ayumu Tashiro
Group leader



Stefan Leutgeb
Group leader (until 2008)

Visiting professors



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Professor
University of Lethbridge,
Canada
Sabbatical visitor



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Professor
University of Arizona,
USA



Bruce McNaughton
Professor
University of Arizona,
USA



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Germany



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University of Edinburgh, UK



Ole Paulsen
Professor
Oxford University,
UK



Alessandro Treves
Professor
International School for
Advanced Studies, Italy

Administration

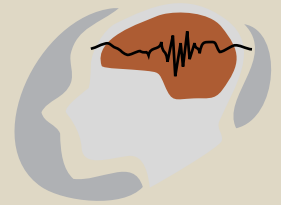


Iuliana Hussein
Office Administrator



Hege J. Tunstad
Head of Information

Who's who at KI/CBM



Research scientists



Laura Colgin
Research Scientist



Karel Jezek
Research Scientist



Dori Derdikman
Research Scientist



Jonathan Whitlock
Research Scientist



Sheng-Jia Zhang
Research Scientist



Natalia Kononenko
Post-doc



Rosamund Langston
Post-doc



Tiffany Cautier
Post-doc



Jay Couey
Post-doc



Emilio Kropff
Post-doc



Noriko Kogenezawa
Post-doc



Kally O'Reilly
Post-doc



Jing Ye
Post-doc



Hideki Kondo
Post-doc



Lisa Marie Giocomo
Post-doc



Marianne Fyhn
Research Scientist (now UCSF)



Torkel Hafting Fyhn
Research Scientist (now UCSF)



James Ainge
Research Scientist (until 2008)



Jill Leutgeb
Research Scientist (until 2008)

Graduate students



Cathrin Barbara Canto
PhD student



Kirsten Brun Kjelstrup
PhD student



Paulo Girão
PhD student



Trygve Solstad
PhD student



Espen Joakim Henriksen
PhD student



Charlotte Boccara
PhD student



Grethe Olsen
PhD student



Tor Kirksola
PhD student



Hanne Stensland
PhD student



Chenglin Miao
PhD student



Li Lu
PhD student



Charlotte Boormeester Alme
PhD student

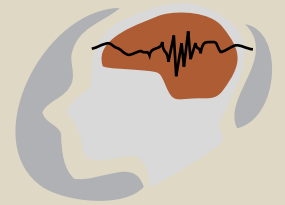
Project students



Tora Bonnevie



Albert Tsao
Kavli Young Investigator



Jørgen Sugar



Magdalene Schlesiger
(until 2008)

Master's students



Henriette Folkvard Hestvaag
Master



Kristian Frøland
Master



Tale Litlere Bjerknes
Master



Gry Fluge Vindedal
Master



Nenitha Charlotte Dagslott
Master



Ida Aasebø
Master



**Stefan Mattias Adriaan
Blankvoort**
Master



Ingvild Ulsaker Kruge
Master



Julia Dawitz
Master



Mathias Lysholt Mathiasen
Master



Veslemøy Mæhle Hult
Master (until 2008)

Technical team



Ingvild Hammer
Infrastructure



Kyrre Haugen
Histology



Klaus Jensen
Electronics



Raymond Skjerpeng
Programming



Haagen Waade
Computers, networks



Ann Mari Amundsgård
Histology, hyperdrives



Ellen Marie Husby
Anatomy



Ragnhild Gisetstad
Anatomy



Alice Burøy
Molecular biology



Endre Kråkvik
Molecular biology, hyperdrives



Bruno Monterotti
Anatomy



Teruyo Tashiro
Neurogenesis



Tommy Åsmul
Animal care



Gudrun Kulbotten Sjøvold
Office Administrator (until 2008)

Associated members



Gerit Pfuhl
PhD student



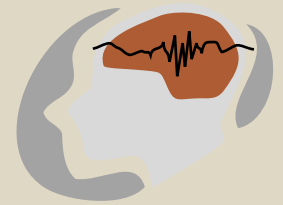
Hanna Mustaparta
*Professor NTNU, (Biology),
Norway*



Hanne Lehn
PhD student



Robert Biegler
*Associate Professor
NTNU (Psychology),
Norway*



Annual accounts

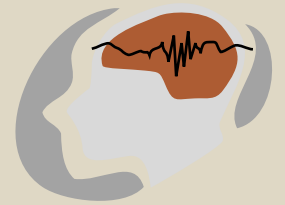
Income in Norwegian Crowns (NOK)

<i>Transferred from 2007</i>	-392 609
Grants	
Norwegian Research Council: Centre of Excellence	10 000 000
Norwegian Research Council: other, including FUGE	16 319 567
International (EU 7th Framework Programme, Fondation Bettencourt-Schueller, James McDonnell Foundation)	5 909 823
Norwegian University of Science and Technology	
S/O funding	3 194 900
Host institution's contribution to operating	3 953 781
Funds to cover overheads	4 966 695
Total income	43 952 157

Expenses in Norwegian Crowns (NOK)

Net personnel costs	16 281 087
Overheads	4 419 688
Scientific equipment	6 053 584
Other expenses	7 749 000
Operational expenses	4 635 189
Total expenses	39 138 548
Transferred to 2009	4 813 609

Publications



Joint publications

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Moser group

Hafting, T., Fyhn, M., Bonnevie, T., Moser, M.-B. and Moser, E.I. (2008). Hippocampus-independent phase precession in entorhinal grid cells. *Nature* 453, 1248-1252.

Solstad, T., Boccara, C.N., Kropff, E., Moser, M.-B. and Moser, E.I. (2008). Representation of geometric borders in the entorhinal cortex. *Science*, 322, 1865-1868.

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Moser, E.I. and Moser, M.-B. (2008). A metric for space. *Hippocampus*, 18, 1142-1156. (lead article for special issue on grid cells).

Witter group

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Canto CB, Wouterlood FG, Witter MP. (2008) What does the anatomical organization of the entorhinal cortex tell us? *Neural Plast.*;2008:381243.

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Tashiro group

Marumoto T, Tashiro A, Friedmann-Morvinski D., Scadeng M., Soda Y., Gage F.H. and Verma I.M. (2008) Development of a novel mouse glioma model using lentiviral vectors. *Nature Medicine*, in press

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Annual Report for KI/CBM 2008



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The Norwegian University of Science and Technology (NTNU) in Trondheim represents academic eminence in technology and the natural sciences as well as in other academic disciplines ranging from the social sciences, the arts, medicine, architecture to fine arts. Cross-disciplinary cooperation results in ideas no one else has thought of, and creative solutions that change our daily lives.

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