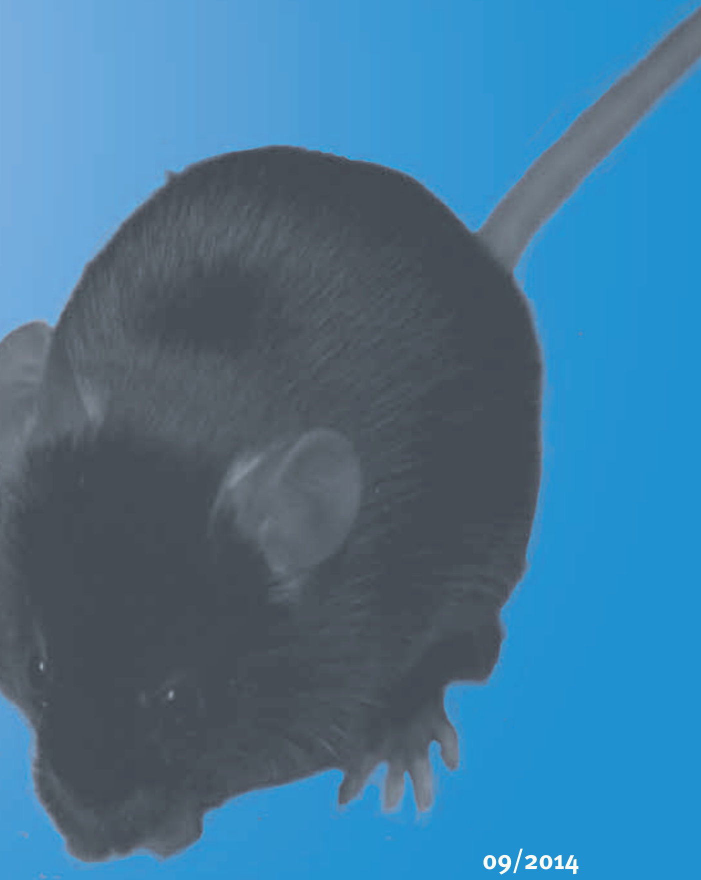
Bernstein Network Computational Neuroscience

Bernstein Newsletter



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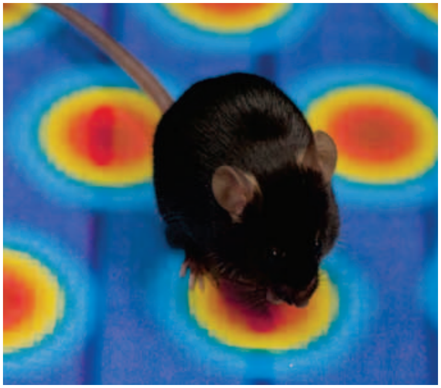
09/2014

Right time, right place



Grid neurons are essential for space orientation. They fire when the mouse happens to be at decisive positions. Seen from above, the activity pattern of a cell forms a hexagonal pattern in space.
© Christina Buetfering, 2014

The food pellet must be further away—a mouse is foraging for food. To estimate distances and to orient itself in space, the brain forms an internal spatial map. So-called grid neurons take on an important role in this process. They fire when the mouse happens to be at decisive positions. From a bird's perspective, the activity pattern of a grid cell forms a hexagonal pattern in space—very reminiscent of a coordinate system on a map (see figure). But how is this abstract activity pattern generated that is not based on sensory input from the environment? To find answers, researchers investigated neuronal connections by means of theoretical models. The currently most promising model is now refuted by scientists from the Bernstein Center Heidelberg/Mannheim and the Department of Clinical Neurobiology at the Medical Faculty of Heidelberg University and The German Cancer Research Center (DKFZ), who put the model to test in animal experiments.

"In our study, we measured the nerve cell activity in freely moving mice," explains Christina Buetfering, first author of the study. "We were interested in grid cells as well as nerve cells that interconnect the grid cells: so-called interneurons". The crucial trick: the activity of interneurons could be selectively switched on and off by light signals in genetically modified mice. While the mice moved around during foraging, the researchers activated the cells now and then. This helped them to identify and closely observe the interneurons in the measured data stream. Also, they were able to analyze how grid cells responded to the activity of interneurons—giving a hint on how the neurons must be connected.

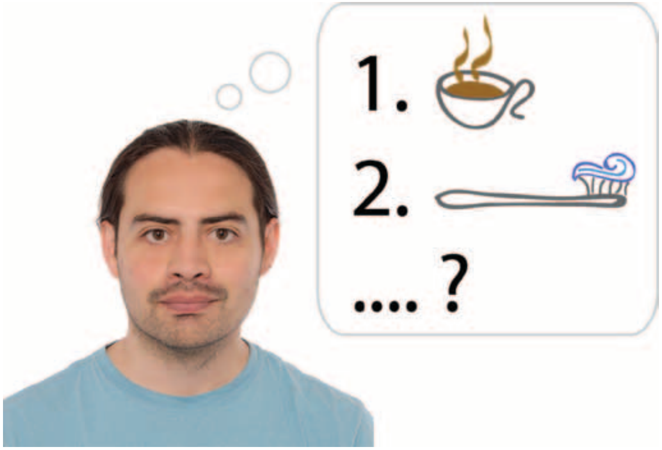
The scientists discovered that interneurons show no spatial activity patterns like grid cells do. In addition, individual interneurons are not exclusively connected to grid cells with similar activity patterns. Instead, they get their input signals from very different grid cells and send their output information to diverse nerve cells. "With these results we were able to refute two basic predictions of the current theoretical network model," Buetfering discusses. "The model assumes that for generating the inner mental map, grid cells of the same spatial orientation must be very closely connected—which was thought to be realized via spatially active interneurons."

However, interneurons seem to have a different main task. The cells send inhibitory signals to quite different neurons in their environment. Therefore, they possibly rather take over a modulating function by ensuring a balance between excitation and inhibition in the brain area during excessive nerve cell activity. In this way they could prevent epileptic seizures. How grid cells manage to fire at the right time at the right place—thereby generating the abstract mental coordinate system—has, once again, become more mysterious.

Buetfering C, Allen K & Monyer H (2014): Parvalbumin interneurons provide grid cell-driven recurrent inhibition in the medial entorhinal cortex. Nature Neuroscience 17, 710–718
doi: 10.1038/nn.3696

Neurons out of sync

This morning, shortly after waking up: did I first go to the bathroom and then turned on the coffee machine in the kitchen—or vice versa? Sometimes you are uncertain whether you have followed an everyday routine as usual or not. The brain has a certain mechanism of storing sequences of spatial events. Part of this mechanism can now be explained by a reasearch team headed by Professor Richard Kempter at the Bernstein Center Berlin and the Humboldt-Universität in Berlin. The study has been published in *The Journal of Neuroscience*. Using a computer model, the scientists are able to predict how some nerve cells may stimulate specific neurons in other brain regions to fire in a specific rhythm.



© Jorge Jaramillo/BCOS, 2014

To analyze how the rhythm comes about, the researchers simulated the behavior of nerve cells in the diverse brain regions on the computer. The result of their model: the rhythm may be passed on from one region to the next and does not need to emerge individually in the respective areas.

“Spatial sequences, such as walking routes, are processed in the hippocampus,” says Jorge Jaramillo, first author of the study. The hippocampus is a structure in the mammalian brain, which is crucial for the explicit memory (facts, events, sequences). Here are neurons, which are responsible for the so-called *place field*: They fire when we find ourselves at a particular point in space.

“If we measure the entire brain activity using EEG (electroencephalography), you see very typical activity oscillations in the hippocampus, the so-called theta rhythm.” Nerve cells that are in the process of encoding spatial information start to fire offset in time to this rhythm. This process creates a complex spatial-temporal pattern of electrical brain activity in the brain, which has an important role in the storage of spatial information. The phase-shifted rhythm has been observed in different subregions of the hippocampus—until now it had been unclear how it arises in the individual areas.

“Ultimately, it allows us to better understand other aspects of memory too, not only spatial, as the basic principles are similar,” says Jaramillo.

Jaramillo J, Schmidt R & Kempter R (2014): Modeling Inheritance of Phase Precession in the Hippocampal Formation. The Journal of Neuroscience, 34(22): 7715 – 7731.
doi: 10.1523/JNEUROSCI.5136-13.2014

Anton Sirota

How many different routes may you take on your way to work? Have you followed the shortest one today? How can we remember routes at all? Anton Sirota is the expert to ask regarding these questions. Spatial navigation, learning, and memory are his main research fields. More specifically, he is interested in the neurophysiological mechanisms of how information is forwarded within and between the neocortex and hippocampus—which is essential for the learning process and the subsequent memory consolidation during sleep. In spring of 2014, Anton Sirota took over the professorship *Cognition and Neural Plasticity* which links the Bernstein Center Munich with the Cluster of Excellence *Munich Cluster for Systems Neurology* (Synergy). He is planning to move his lab soon to a new space at Biocentrum campus of the Ludwig-Maximilians-University Munich (LMU).

Anton Sirota grew up in Russia and studied applied mathematics and physics at the prestigious Moscow Institute of Physics and Technology—or PhysTech in short. In his master thesis he dealt with the theory of memory storage in artificial neural networks. He planned to continue research in the field and decided to expand his knowledge in biology: “I wanted to understand how real biological networks operate,” Sirota says “to be able to build even more realistic artificial networks.” He started looking for a laboratory where he could acquire the necessary background knowledge and eventually started his PhD with György Buzsáki at Rutgers University in New Jersey (USA). It did not take long until the physicist became deeply fascinated by the diversity and complexity of biological mechanisms. “At the same time I realized that my current neurobiological knowledge is still so limited that before going on with in-depth modeling I need to learn much more about the brain itself. This is when I decided to mainly focus on experimental neuroscience.”

The topic of his PhD thesis was the interaction between the neocortex and hippocampal networks. “You first need to understand the symphony an orchestra is playing before you can turn to the individual melodies of the single musical instruments,” Sirota describes his approach. The hippocampus and the neocortex have a very peculiar harmony: they generate interacting rhythms of activity. These ensure that local networks in both brain areas are simultaneously active—and that information can be passed from the neocortex to the hippocampus during the encoding phase of our memory. Notably, the process is reversed while we sleep: now memory contents are replayed from the hippocampus to the neocortex. The clock of the rhythm that links the two structures together is emerging from the respective brain area that receives the information. During his PhD and a subsequent postdoctoral training in Buzsáki’s lab, Sirota studied the dynamics of these oscillations by means of electrophysio-logical recordings in rodents. It was during this time when he discovered that slow oscillations—a hallmark of deep sleep—are indispensable for coordinating the hippocampal replay of information, and are therefore a prerequisite for memory consolidation.

After ten years in the United States, Anton Sirota took the next step of becoming a junior group leader in 2009. He moved to Germany to establish a research group at the Cluster of Excellence *Centre for Integrative Neurosciences* at the University of Tübingen. Here he included an important but still missing tool in his research repertoire: quantitative behavioral observations.

They are an important aspect during the learning phase. “When an animal explores space, nothing happens by chance. Behavior rather follows an internal ‘order’. For example, when a rat rears and starts sniffing, it directs attention specifically to the odor features of its environment,” Sirota says. To examine rodent behavior, Sirota has adopted a complex three-dimensional tracking system that consists of multiple cameras. Small markers attached to the body of the animal help recording its movements with high spatial and temporal resolution. Sirota combines this information with simultaneously recorded brain signals during his analyzes. “We have found evidence that the different kinds of exploratory behavior and the transitions between them are reflected in the activity of the hippocampus. This could be associated with attention to particular aspects of sensory world, a feature so important in learning,” he speculates—a hypothesis which he plans to pursue in the Bernstein Center Munich. Sirota is convinced that spatial information is an important accessory in memory processes. “Space offers a very helpful structure to anchor memory contents. Mnemonic techniques often take advantage of this, such as when we mentally place products of a shopping list along a fictive street in order to remember them more easily at the supermarket.”

The Bernstein Center Munich with its research focus in space representation provides a perfect environment for Anton Sirota. His wife Caroline Geisler, who completed a postdoctoral stay in the same laboratory as he did, will start a position in Andreas Herz’s research group. Sirota is looking forward to fruitful collaborations with local scientists. He is particularly keen to push the technological development in the electrophysiology field. Among other things, Sirota and his group have developed extracellular electrodes that may record the activity of neuronal populations in all layers of a cortical column. He combines this technique with optogenetic stimulation to study the dynamics of neuronal activity. At the moment, Sirota is working on improving the combination of the two methods in order to better localize the readout of neural signals in deep brain areas.

Aside from his research, spatial orientation plays a role in Sirota’s private life, too: he is a passionate mushroom picker who likes to go hiking in nature with his family. The Munich area holds many opportunities for these hobbies: “I am looking forward to forests, lakes and mountains.”

Valentino Braitenberg Award 2014 goes to Alexander Borst

On September 3rd, 2014, at 5 p.m.—within the framework of the Bernstein Conference in Göttingen—the second Valentino Braitenberg Award for Computational Neuroscience will be presented to Alexander Borst from the Max Planck Institute of Neurobiology in Martinsried.

Main research focus of the biologist is neural information processing at the level of individual neurons and small neural circuits. As an example for neural computation, Alexander Borst studies visual course control in the fruit fly Drosophila. “This is a tractable system for the following reasons: It involves computations of modest complexity, these computations are implemented in circuits that contain a rather limited number of neurons—typically less than 100—and each of these neurons can be genetically targeted allowing manipulation and recording of its activity,” Borst explains.

For a comprehensive picture of information processing in the visual system, Alexander Borst combines precise anatomical reconstructions of the neuronal elements with detailed characterizations of their physiological response properties and their functional role in behavior. Computational modeling allows him and his research group to confirm their findings in a theoretical framework and make predictions for future experiments. Finally, they use their knowledge to engineer artificial flying vehicles equipped with camera systems that implement fly-inspired motion detection algorithms.

Alexander Borst received his PhD from Julius Maximilians Unversity of Würzburg in 1984. Afterwards, he worked for several years at the Max Planck Institute for Biological Cybernetics in Tübingen before he became junior group leader at the Friedrich Miescher Laboratory in Tübingen in 1993. In 1999, he joined the University of California in Berkeley. Since 2001, he is director at the Max Planck Institute of Neurobiology in Martinsried. Together with his department, Alexander Borst is part of the Bernstein Center Munich and the Bernstein Collaboration “Neural Network Simulation”. Alexander Borst is a member of the German National Academy of Sciences Leopoldina and the Bavarian Academy of Sciences and Humanities. Among others, the 56-year-old researcher has been honored with the Otto Hahn Medal of the Max Planck Society and the FENS award.

The Valentino Braitenberg Award for Computational Neuroscience is presented biannually by the Bernstein Association for Computational Neuroscience e.V. to a scientist in recognition of outstanding research that contributes to our understanding of brain functions. In the spirit of Valentino Braitenberg’s research, special emphasis is given to theoretical studies. The awardee receives a € 5000 prize donated by the *Autonome Provinz Bozen Südtirol*, as well as complimentary participation in the Bernstein Conference. The prize will be awarded together with a Golden Neuron pin badge in a special ceremony at the Bernstein Conference 2014 in Göttingen. During the subsequent Valentino Braitenberg Lecture, Alexander Borst will present highlights of his research career.
www.nncn.de/en/news/nachrichten-en/second-braitenberg-award-goes-to-alexander-borst

Bernstein Center Freiburg places new focus on brain diseases

The Bernstein Center Freiburg (BCF) is about to establish a new research focus on brain diseases, exploring their causes at the level of nerve cells and neuronal networks. The Carl Zeiss Foundation supports the BCF in developing and implementing new research approaches, where animal experiments and clinical approaches are complemented by modern computer-based and mathematical methods. Funds amounting to 750,000 Euro will allow the scientists to carry out important build-up work over the next four years.

So far, the BCF has focused on basic research in computational neuroscience and neurotechnological applications that are derived from it. New support by the Carl Zeiss Foundation will now allow to also systematically investigate the neuronal mechanisms of neurological and psychiatric diseases. Research conducted in Freiburg already made significant contributions to the understanding of diseases like epilepsy and Parkinson's.

"Many dysfunctions of the brain can probably be traced back to alterations in the activity dynamics of neuronal networks. Here, our work will contribute to a better understanding in the future," explains Stefan Rotter, director of the BCF. Among other things, the new research will help to establish the necessary bridging between clinical sciences and basic research.

Management of research projects, technical support in the field of high performance computing, and communication of findings and methods to students and colleagues are involved and must be mastered in addition to the actual research. The Carl Zeiss Foundation enables the BCF to fund staff who support the scientists in these tasks and assist in the strategic development of the new research focus.

www.bcf.uni-freiburg.de/news/20140812-carl-zeiss-funding

Personalia

Hermann Wagner (Bernstein Collaboration temporal precision, RWTH Aachen University) was elected as a regular member of the mathematical-natural sciences class of the Academy of Sciences and Literature Mainz.

www.nncn.de/en/news/nachrichten-en/hermann-wagner

Arab, Israeli and German scientists met in Göttingen

From July 29 to 31, 2014, the international conference NeuroBridges took place for the first time at the Max Planck Institute for Dynamics and Self-Organization in Göttingen. It brought together Arab, Israeli, and German neuroscientists with the aim to promote both scientific collaborations as well as cross-cultural understanding between the participants.

"From a scientific point of view, we intend to foster an exchange between experimental and theoretical neuroscientists," says Ahmed El Hady at the Bernstein Center for Computational Neuroscience Göttingen. He is one of three members of the conference organizing committee which also includes Tim Gollisch at the Bernstein Center Göttingen and Yonatan Loewenstein at the Hebrew University of Jerusalem (Israel). To encourage the scientific dialogue, the conference participants reported on their latest findings in the field of Systems and Computational Neuroscience. The topics ranged from research on memory function to epilepsy and brain-machine interfaces.

Aside from the scientific discussion, the organizers regard the intercultural exchange as an important goal of the event. "We think that scientists have a responsibility beyond their own research—they should promote common understanding between people from different nations," El Hady explains. The organizers invited 21 speakers; seven of them are Arab, seven Israeli, and seven German scientists. The side program, which included a dinner and a city tour, was designed to encourage personal exchange of ideas and to establish new collaborations between the participants. "Scientific collaborations often lead to personal relations and may therefore—in the long run—alleviate the political distress between Arabs and Israelis," El Hady describes his hopes. The NeuroBridges symposium is thought to be the start of an anually held symposium for Arab, Israeli, and German neuroscientists.

www.idw-online.de/de/news598059
http://bio.huji.ac.il/yonatanLab/newsite/site.html

Bernstein Blog *HirnNetze* launched

To inform the general public about findings of scientists from the Bernstein Network and at the same time provide an opportunity for discussions, the Bernstein Network has launched the blog *HirnNetze—hinter den Kulissen eines Forschungsnetzwerks* in August 2014. The blog provides a great occasion for a peek behind the curtains of a large research network. Scientists—from students to postdocs to principal investigators—report about their everyday work life and research results in order to encourage lively discussions with other authors and readers.

Visit the blog under the URL:

www.scilogs.de/hirnnetze

The Bernstein Network is looking forward to a lively and inspiring exchange!

Bernstein Network – SimLab Neuroscience: HPC Workshop

The Bernstein Network – SimLab Neuroscience: High Performance Computing (HPC) Workshop was held from June 4 to 5, 2014, at the Jülich Supercomputing Centre (JSC) at Forschungszentrum Jülich. The aim of the workshop was to establish new contacts for common projects and collaborations between the Jülich Simulation Laboratory (SimLab) Neuroscience, the Bernstein Facility for Simulation and Database Technology, and neuroscientific research groups.

The participants presented their current research topics in short talks. Members of the SimLab Neuroscience gave an overview of its activities and collaboration models and presented some projects in collaboration with Jülich scientists in greater detail. The SimLab supports neuroscientists in exploiting supercomputer resources, but also follows its own research goals in the fields of High Performance Computing (HPC) and neuro-science. Scientists from the JSC gave an introduction into supercomputing as well as a short overview of the technology of the supercomputers in Jülich, the available software packages and the application process for compute time for the JSC machines. The SimLab Neuroscience also supports neuroscientists in preparing their proposals for compute time.

www.nncn.de/en/news/nachrichten-en/hpc-workshop

www.fz-juelich.de/ias/jsc/slns

Participants of the Bernstein Network - SimLab Neuroscience: HPC Workshop.

Research Training Group at BCCN Berlin successfully extended

The German Research Foundation (Deutsche Forschungsgemeinschaft, DFG) funds the Research Training Group 1589/2 *Sensory Computation in Neural Systems* with approximately € 2 Mio for further 4.5 years. The Research Training Group (RTG) is coordinated by Klaus Obermayer (BCCN and BFNT Berlin, BFNL complex human learning, BCOL memory network, D-USA Collaboration, TU Berlin) and brings together researchers from the fields of cognitive science, machine learning, animal physiology, artificial intelligence, neural imaging and stochastics, which provide for interdisciplinarity and diversity of research and teaching.

In 2010, the Research Training Group was established by the Technische Universität Berlin and the Bernstein Center for Computational Neuroscience Berlin (BCCN Berlin) in cooperation with the Charité-Universitätsmedizin Berlin, the Humboldt Universität zu Berlin and the Freie Universität Berlin. This second funding period will contribute essentially to the excellent research and teaching activities at the interface between informatics, neuroscience, mathematics, physics and technical disciplines in Berlin. Since the start of the RTG, 46 students from 13 countries worked on different projects. The structured program additionally offers subject-specific training as well as training for the acquisition of complementary skills. Seven fellows of the new funding period will start their doctorate in October 2014.

www.pressestelle.tu-berlin.de/medieninformationen/2014/mai_2014/medieninformation_nr_1072014 (in German)

Upcoming Events

Date	Title	Organization	URL
Sept. 2.–5., 2014, Göttingen	Bernstein Conference 2014 Workshops: 2-3 Sept 2014 Main Conference: 3-5 Sept 2014	F. Wörgötter (BFNT and BCCN Göttingen, D-J Collaboraiton), K. Mosch and Y. Reimann (BCCN and BFNT Göttingen), Bernstein Coordination Site (BCOS)	www.bernstein-conference.de
Sept. 8—13, 2014, Split, Kroatien	G-Node Summer School “Advanced Scientific Programming in Python“	T. Zito (BCCN Berlin, G-Node), Z. Jedrzejewsky-Szmek (G-Node), L. Periša, I. Kajic (BCCN Berlin), I. Balaževic, F. Petkovski	http://python.g-node.org
Sept. 8—12, 2014, Göttingen	12th Summer Course on Computational Neuroscience (hosted by BCCN Göttingen)	M. Puelma-Touzel, A. Palmigiano, J. Liedtke	www.bccn-goettingen.de/events/cns-course
Sept. 13, 2014, Yokohama, Japan	Symposium: Network of Attention in Human and Macaque within the framework of the 37th Annual Meeting of the Japan Neuroscience Society	M. Puelma-Touzel, A. Palmigiano, J. Liedtke	www.nncn.de/en/news/events/symposium-network-of-attention-in-human-and-macaque
Sept. 13, 2014, Yokohama, Japan	Symposium: Quarter Century after the Direct and Indirect Pathways: Towards Comprehensive Understandings of the Basal Ganglia within the Framework of the 37th Annual Meeting of the Japan Neuroscience Society	A. Nambu (Japanese Partner of Fred Hamker in D-J Collaboration: The function and role of Basal Ganglia pathways: From single to multiple loops. Within the symposium results of the D-J Collaboration will be presented)	www.nncn.de/en/news/events/symposium-basal-ganglia
Sept. 15—19, 2014, Hamburg	International Conference on Artificial Neural Networks (ICANN)	S. Wermter, A. E. P. Villa, W. Duch, P. Koprinkova-Hristova, G. Palm, C. Weber (BFNT Frankfurt), T. Honkela, S. Magg, J. Bauer, J. Chacon, S. Heinrich, D. Jirak, K. Koesters, E.Strahl	http://icann2014.org
Sept. 22—25, 2014, Cloister Heiligkreuztal	Tübingen International Summer School 2014 EMPATHY & SOCIAL INTERACTION — Mechanisms, disorders, social implications	R. Conrad, D. Gerstorfer, A. Lindner (BCCN Tübingen), K. Volz	www.forum-scientiarum.uni-tuebingen.de/tiss

Upcoming Events

Date	Title	Organization	URL
Oct. 5–10, 2014, Freiburg	BCF/NWG Course: Analysis and Models in Neurophysiology	S. Rotter, U. Egert, C. Mehring, B. Ahrens (all Bernstein Center Freiburg), R. Schmidt	www.bcf.uni-freiburg.de/events/conferences-workshops/20141005-nwgcourse
Oct. 27–28, 2014, Tübingen	2014 Tübingen MEG Symposium	Mitorganisator: C. Braun (BFNT Freiburg-Tübingen)	http://meg.medizin.uni-tuebingen.de/2014
Nov. 15–19, 2014, Washington DC, USA	Neuroscience 2014 with Bernstein Network Information Booth	Society for Neuroscience (SfN)	www.sfn.org/annual-meeting/neuroscience-2014
Nov. 27–28, 2014, Jülich	Introduction into Programming and Usage of Supercomputer Resources in Jülich	Forschungszentrum Jülich	www.fz-juelich.de/SharedDocs/Termine/IAS/JSC/EN/courses/2014/percomputer-2014-11.html
Dec. 1–3, 2014, Jülich	Introduction to Parallel Programming with MPI and OpenMP (Courses given in German)	Forschungszentrum Jülich	www.fz-juelich.de/SharedDocs/Termine/IAS/JSC/EN/courses/2014/mpi-2014.html

The Bernstein Network

Chairman of the Bernstein Project Committee: Andreas Herz

The National Bernstein Network Computational Neuroscience (NNCN) is a funding initiative of the Federal Ministry of Education and Research (BMBF). Established in 2004, it has the aim of structurally interconnecting and developing German capacities in the new scientific discipline of computational neuroscience and, to date, consists of more than 200 research groups. The network is named after the German physiologist Julius Bernstein (1835–1917).

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