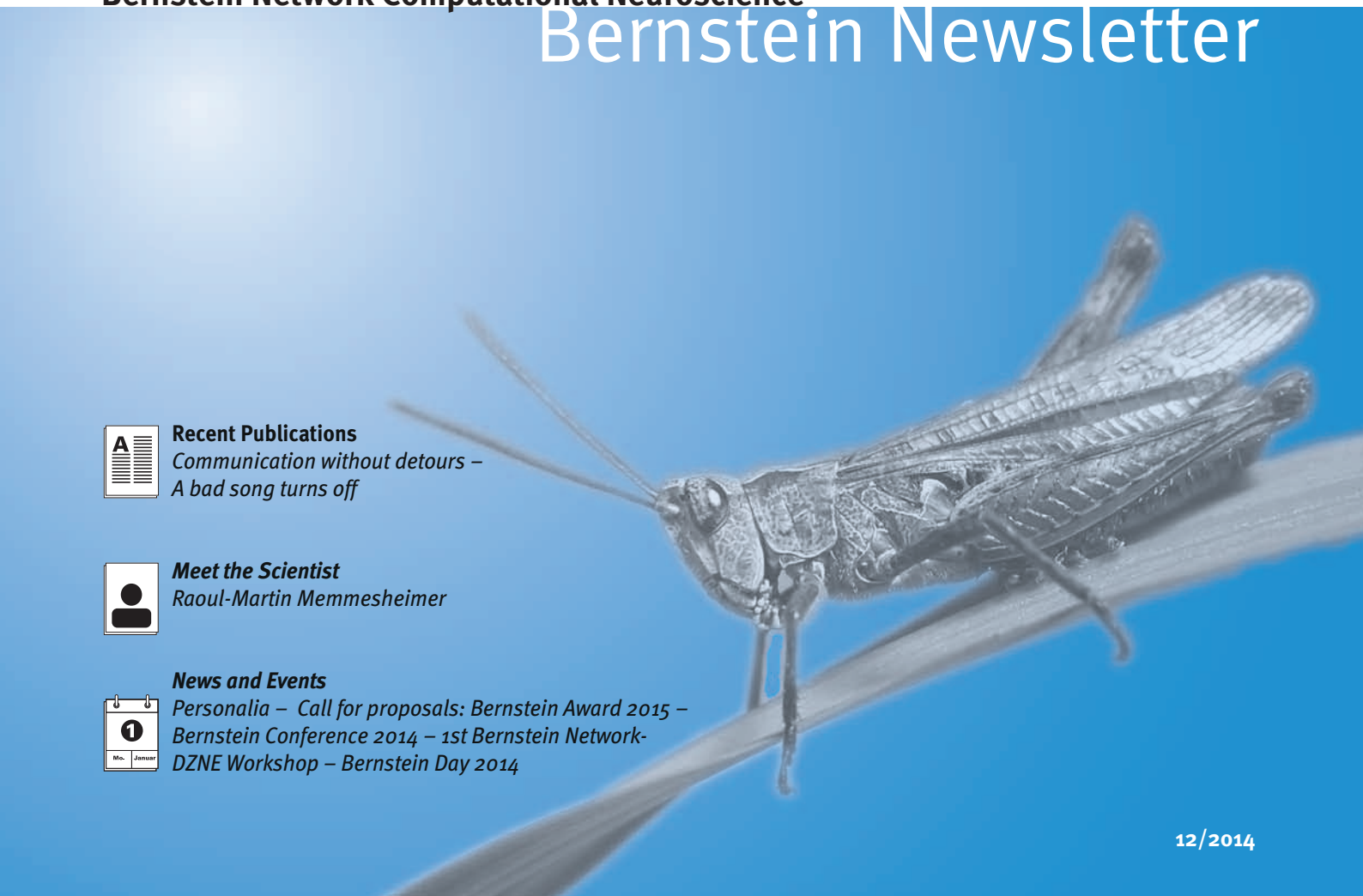
Bernstein Network Computational Neuroscience

Bernstein Newsletter



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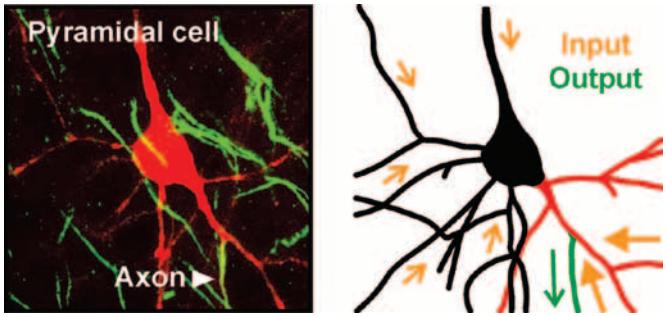
Communication without detours

Nerve cells communicate by using electrical signals. Via widely ramified cell structures—the dendrites—, they receive signals from other neurons and then transmit them over a thin cell extension—the axon—to other nerve cells. Axon and dendrites are usually interconnected by the neuron's cell body. A team of scientists at the Bernstein Center Heidelberg-Mannheim, Heidelberg University, and the University of Bonn has now discovered neurons in which the axon arises directly from one of the dendrites. Similar to taking a bypass road, the signal transmission is thus facilitated within the cell.



A neuron in which the axon originates at a dendrite. Signals arriving at this dendrites become more efficiently forwarded than signals input elsewhere.

"Input signals at this dendrite do not need not be propagated across the cell body," explains Christian Thome of the Bernstein Center Heidelberg-Mannheim and Heidelberg University, one of the two first authors of the study. For their analyses, the scientists specifically stained the places of origin of axons of so-called pyramidal cells in the hippocampus. This brain region is involved in memory processes. The surprising result: "We found that in more than half of the cells, the axon does not emerge from the cell body, but arises from a lower dendrite," Thome says.

The researchers then studied the effect of signals received at this special dendrite. For this purpose, they injected a certain form of the neural transmitter substance glutamate into the brain tissue of mice that can be activated by light pulses. A high-resolution microscope allowed the neuroscientists to direct the light beam directly to a specific dendrite. By the subsequent activation of the messenger substance, they simulated an exciting input signal.

"Our measurements indicate that dendrites that are directly connected to the axon, actively propagate even small input stimuli and activate the neuron," says second first author Tony Kelly, a member of the Sonderforschungsbereich (SFB) 1089 at the University of Bonn. A computer simulation of the scientists predicts that this effect is particularly pronounced when the information flow from other dendrites to the axon is suppressed by inhibitory input signals at the cell body.

"That way, information transmitted by this special dendrite influences the behavior of the nerve cell more than input from any other dendrite," Kelly says. In a future step, the researchers attempt to figure out which biological function is actually strengthened through the specific dendrite—and what therefore might be the reason for the unusual shape of these neurons.

Thome C, Kelly T, Yanez A, Schultz C, Engelhardt M, Camebridge SB, Both M, Draguhn A, Beck H and Egorov AV (2014): Axon-Carrying Dendrites Convey Privileged Synaptic Input in Hippocampal Neurons. Neuron, 83: 1418 – 1430.
doi: 10.1016/j.neuron.2014.08.013

A bad song turns off

A grasshopper of the species Chorthippus biguttulus*, which the scientists examined in the study.* © Monika Eberhard, 2014

Which mating partner is the best? To answer this difficult question, female grasshoppers base their decision on the singing skills of their male conspecifics. In the process, the quality of bad singers has much bigger weight than the one of good singers. The latter has a negligible influence on the decision of females. This is the result of a study by researchers lead by Bernhard Ronacher at the Bernstein Center Berlin and the Humboldt-Universität in Berlin. The scientists point out that their research results are consistent with current theories of sexual selection: it helps females to avoid time and cost-intensive contacts with unsuitable mating partners—such as with males of other species, which have distinct calling songs.

For the study, the researchers presented female grasshoppers with male calling songs in a sound-isolated chamber. When a female likes a song, it produces a response, which in turn encourages the male in its courtship behavior. "The animals evaluate song subunits with a more or less constant volume as being most attractive", explains Jan Clemens, first author of the study. The scientists presented both attractive and non-attractive calling songs to the animals and recorded the female responses to investigate the decision process in the animals.

"We found that especially the beginning of a song has a strong influence on the response of the females," says Clemens. This could mean that grashopper females are easily coerced into mating with a male after a few good syllables—which contradicts current theories of sexual selection, however. These postulate that females should be choosy and should therefore evaluate well if the males may produce good songs over a longer time period, too.

To unravel the dynamics of decision making in more detail, the researchers analyzed their data using a computational model. This model allowed them to consider further parameters in the analysis of the behavioral data, such as the weight of sensory information in the decision process, or the internal decision threshold of the animal.

"Interestingly, this model provided us with a very different explanation: a bad song has much more weight than a good one during the decision making process. This interpretation is far more consistent with current theories of sexual selection, since it helps to prevent disadvantageous mate choices," says Clemens. The neuroscientist alludes to the expanded analysis opportunities of computational models. It was the model that helped them to disentangle the behavior of female grashoppers and revealed that the animals are not reacting impulsively to good songs but rather selectively reject "bad" ones.

Clemens J, Krämer S, Ronacher B (2014): Asymmetrical integration of sensory information during mating decisions in grasshoppers. PNAS, advanced online publication
doi: 10.1073/pnas.1412741111

Raoul-Martin Memmesheimer

How do groups of nerve cells process information? What is the role of signals that are timed on the precise millisecond? And how can a network of nerve cells learn to produce a specific rhythm of signals? These questions are part of Raoul-Martin Memmesheimer's research focus: "I am interested in the temporal characteristics of electrical signals that neurons in biological neural networks use to communicate with each other," Memmesheimer says. His tools are theoretical models. On their basis the physicist wants to reconstruct and understand the complex dynamics of medium-sized nerve cell networks. His research takes place in close relation to experimental science: "We incorporate biological data in our network models," he describes, "and our theoretical models make concrete predictions, which are then investigated in real neural populations by experimental neuroscientists." In September of this year, Memmesheimer received the Bernstein Award 2014.

Raoul-Martin Memmesheimer developed a broad scientific interest from early on. While in school, he participated in *Schüler experimentieren*—a regional youth research competition in Germany—and in various competitions in mathematics and Latin. However, from the beginnings of his university studies on, his main focus lay clearly in the natural sciences. Memmesheimer used the early admission program at TU Kaiserslautern to start studying physics by distance learning while still completing the compulsory military service. The double challenge was worth it: "After the service, I was able to enter straight into the third semester." Memmesheimer stayed another year in Kaiserslautern to finish his Vordiplom before he moved to Munich, and later to Jena, where he wrote his diploma thesis in the area of general relativity on symmetries in systems of two black holes. It was for his dissertation that he made the step from theoretical physics to theoretical neuroscience by joining the research group *Network Dynamics* of Marc Timme, and pursuing his PhD both under his and Theo Geisel's supervision at the Max Planck Institute for Dynamics and Self-Organization in Göttingen. "The idea to enter brain research as a physicist came into my mind through Wolf Singer, who always pointed out in his lectures that the neurosciences needed theoretical physicists," Raoul-Martin Memmesheimer recalls. Theoretical neurosciences as an emerging field with a broad explanatory claim beyond science appealed to the young physicist. In particular, he was fascinated by network theories with their manifold applicability. Consequently, in his doctoral thesis, Memmesheimer dealt with complex networks of spiking neurons and their dynamics—that means, neuronal models in which action potentials are taken into account.

"During my PhD, I examined different aspects of temporal precision of nerve cell activity," Memmensheimer explains. "One research question explored the situation when several signals arrive at a nerve cell at the same time, which may lead to a strong enhancement of the signal. What are the effects of non-linearity on the dynamics of recurrent networks?" The impact of this effect is difficult to examine in living systems. Using his models, Memmesheimer revealed that it leads to characteristic rhythmic oscillations in the network. Subsequently, he learned: these rhythms actually exist in the hippocampus, the "memory center" of the brain.

Meet the Scientist

After his doctoral thesis—for which he was awarded with Otto Hahn Medal of the Max Planck Society and an award of Göttingen University—Raoul-Martin Memmesheimer moved to Harvard University (USA), where he worked as an independent Swartz Fellow with Haim Sompolinsky. Now, his main research question was to examine how neurons accomplish to respond to an input at a specific time. "For example, if a bird wants to produce a certain song, it needs very precisely timed neural signals," Memmesheimer says. "How can a songbird control if it generates the correct signal pattern?" Initially, it looked like a relatively theoretical question—however, it entailed a surprising number of concrete applications in the course of the project. Memmesheimer and his colleagues designed a universal learning theory for precise spike patterns that can be widely employed for data analysis. For instance, it can be used to extract the information content contained in a sequence of neural signals that is available to the brain. "A songbird must analyze the activity of approximately 300 neurons in order to exactly determine if its singing tune shows the correct rhythm."

A further application is the reconstruction of neural networks based on known activity pattern. "The idea behind is to take spike trains—or signal sequences—from a network and enter them into the model with the order to let the model learn to produce this exact activity pattern. Over time, the behavior of the model converges with the target," Memmesheimer explains. From this, he can draw conclusions about the connections of the original neurons that have generated the activity pattern. "I am delighted by the broad applicability of the learning model. It is just as Max Planck said: 'insight must precede application'. First, we have seen how learning may take place, and then the applications arose."

Since April 2010, Raoul-Martin Memmesheimer is assistant professor in the Department for Neuroinformatics at the Donders Institute at Radboud University in Nijmegen. Next to teaching and following new research projects, Memmesheimer has kept an emphasis on the continuation of the projects on learning theory for precise spike patterns with Haim Sompolinsky, and on nonlinear network dynamics with Marc Timme and Sven Jahnke. With the investigation of medium-sized neural networks—comprising some hundreds to thousands of neurons—he wants to contribute to closing the knowledge gap between the relatively well examined level of individual nerve cells and whole brain areas. On the one hand, this will help to understand the link between individual neurons and the entire brain's activity. On the other hand, Memmesheimer's findings facilitate artificial intelligence research. In the long term, he wants to develop highly biologically inspired algorithms that can recognize and predict temporal patterns. "This could be used to design even more sophisticated robots," the neuroscientist says.

Raoul-Martin Memmesheimer considers to use the Bernstein Award to build up his own research group in Göttingen to pursue the questions on the temporal network dynamics in the brain. This way, he could deepen the already existing collaboration with Marc Timme and kick off further projects with Fred Wolf and Florentin Wörgötter at the Bernstein Center and the Bernstein Focus Neurotechnology. At the same time, Memmesheimer intends to work even more closely with experimental researchers: in a joint research project with Andreas Draguhn in Heidelberg, he wants to analyze how activity patterns in the hippocampus contribute to learning. "The Bernstein Award gives me the opportunity to quickly realize my main research projects," Memmesheimer is pleased. As a private wish, the scientist hopes to devote a little more time to playing the violin: "I will probably join a university orchestra again."

Personalia

Marlene Bartos (Bernstein Center Freiburg and Faculty of Medicine, University of Freiburg) coordinates the new Research Unit *Synaptische Plastizität GABAerger Zellen – vom Mechanismus zur Funktion* (Synaptic plasticity of GABAergic cells—from mechanism to function) that is funded by the German Research Foundation (*Deutsche Forschungsgemeinschaft*, DFG) with € 2.4 million over the next three years.
www.nncn.de/en/news/nachrichten-en/research-unit

Volker Pernice receives the Hans Spemann Award of the *Dr.-Gerhard-Fritz-Stiftung des Verbandes der Freunde der Universität Freiburg im Breisgau e.V.* for his outstanding PhD thesis, which he has conducted at the Bernstein Center Freiburg.
www.nncn.de/en/news/nachrichten-en/volker-pernice

Stephan Sigrist (Bernstein Center and Freie Universität Berlin) was appointed Einstein Professor. The funding by the Einstein Foundation Berlin supports the expansion of Stephan Sigrist's laboratory, in which a multidisciplinary team of neuroscientists and geneticists works together.
www.nncn.de/en/news/nachrichten-en/sigrist-einstein

Surjo R. Soekadar (Bernstein Focus: Neurotechnology Freiburg-Tübingen, University of Tübingen) was honored with the Young Investigator Award at the 19th International Conference on Biomagnetism for his work on the characterization of the so-called *Bereitschaftskomplexität* and the development of a new strategy allowing for assessment of neuromagnetic activity during electric brain stimulation.
www.nncn.de/en/news/nachrichten-en/soekadar-award

Henning Sprekeler (Bernstein Award 2011, D-J Collaboration) was appointed professor for *Modelling of cognitive processes* at the Technische Universität and the Bernstein Center Berlin in October 2014.
www.nncn.de/en/neues/nachrichten/henning-sprekeler-new-professor-at-bccn-berlin

New call for proposals: Bernstein Award 2015

In 2015, the German Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung, BMBF) will confer the tenth annual Bernstein Award to an excellent young scientist with outstanding research ideas in the field of Computational Neuroscience. The *Bernstein Award for Computational Neuroscience* is endowed with up to € 1.25 Mio for a period of five years, and allows young scientists from all nations to establish an independent research group at a German university or research institution. Application deadline for the year 2015 is April 15, 2015.
www.nncn.de/en/news/nachrichten-en/call-for-proposals-bernstein-award-2015

Bernstein Conference 2014

The 10th Bernstein Conference took place in Göttingen from September 2-5, 2014. For the second time, satellite workshops were held prior to the conference on September 2 and 3. The conference was organized by the Bernstein Focus Neurotechnology Göttingen under the direction of Florentin Wörgötter. About 500 participants attended the conference. All conference abstracts—summing up to more than 290—were published on the server of the German INCF Node (G-Node) under the following link: www.g-node.org/abstracts/bc14

Bernstein Award 2014

As in previous years, the prize giving ceremony of the Bernstein Award was a highlight of the conference. Dr. Georg Schütte, State Secretary at the Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung, BMBF), presented the award to Raoul-Martin Memmesheimer (Radboud University Nijmegen, the Netherlands). The Bernstein Award is endowed with up to € 1.25 Mio., constituting one of the best remunerated young scientists' awards. By means of the Bernstein Award, Raoul-Martin Memmesheimer will investigate neuronal networks (s. also portrait).

Dr. Georg Schütte (right) and Dr. Raoul-Martin Memmesheimer (left).

Brains for Brains Award

For the fifth time, the Bernstein Association for Computational Neuroscience awarded the *Brains for Brains Young Researchers' Computational Neuroscience Award*. This year's awardee was Ben Shababo (Helen Wills Neuroscience Institute, UC Berkeley). The award was made possible through donations by Multi Channel Systems MCS GmbH, npi electronic GmbH, and circular Informationssysteme GmbH.

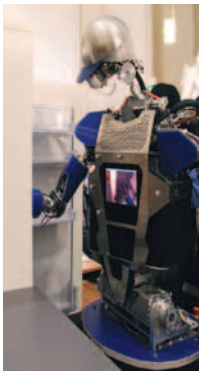
Andrea Huber Brösamle (Bernstein Coordination Site, left), Ben Shababo (center), Karl-Heinz Boven (Multi Channel Systems MCS GmbH, right).

Fellow from the US-American Sloan-Swartz Centers

Within the exchange program between the Bernstein Network and the Sloan-Swartz Centers for Theoretical Neurobiology, the Bernstein Focus Neurotechnology Göttingen funded the participation of the American postdoc Yu Hu (Center for Brain Science, Harvard University) in the Bernstein Conference 2014.

Events for the broad public

The general public was invited to two events in order to learn about latest research developments. On September 2, within the framework of the PhD student event *Mind the gap: Can the puzzle of consciousness be solved*, Joseph Levine und Giulio Tononi provided insights into consciousness research. On September 4, Tamim Asfour presented current and future research topics in the field of humanoid robotics.



humanoid roboter ARMAR III

Information booth of the Bernstein Network

Meet the Expert: Udo Ernst (left) and Ilka Diester (right)

For the first time, the Bernstein Network presented itself with an information booth at the Bernstein Conference. The booth was also used for special activities, such as *meet the expert* events where students and postdocs could discuss with former Bernstein Award winners and live demonstrations by G-Node and the Bernstein Facility for Simulation and Database Technology.
www.nncn.de/en/news/nachrichten-en/bernstein-konferenz

1st Bernstein Network - DZNE Workshop took place in Freiburg

On October 20 and 21, 2014, the first joint workshop of the German Center for Neurodegenerative Diseases (DZNE) and the Bernstein Network Computational Neuroscience (NNCN) took place at the Bernstein Center Freiburg (BCF). Within the framework of the workshop, 20 scientists of the DZNE and the NNCN explored perspectives for future cooperations.

DZNE and NNCN scientists introduced themselves through a "Scientific Speed Dating" and then presented the focus of their research work as well as the methodological approaches in short lectures. On this basis, areas of common interest were identified, topic-specific working groups formed, and ideas for potential cooperation projects gathered. The results were then presented to the plenary.

As a next step, DZNE and NNCN scientists are now called upon to develop joint project proposals that will be presented during a second workshop, which is scheduled to take place in Spring 2015. Interested DZNE and NNCN scientists may contact Andrea Huber Brösamle for further information (e-mail: andrea.huber@bcos.uni-freiburg.de).

Organizers of the workshop were Stefan Rotter (Bernstein Center Freiburg), Markus Diesmann (Forschungszentrum Jülich), Andrea Huber Brösamle (Bernstein Coordination Site), Pierluigi Nicotera (German Center for Neurodegenerative Diseases, Bonn), Alexander Migdoll (German Center for Neurodegenerative Diseases, Bonn), Mareike Kardinal, Kerstin Schwarzwälder and Petra Stromberger (all three Bernstein Coordination Site).

www.nncn.de/en/news/nachrichten-en/1st-bernstein-network-dzne-workshop

Information day about Computational Neuroscience graduate programs

On January 14, 2015, the Bernstein Center (BCCN) Berlin will hold an information day about the Master and the PhD program in Computational Neuroscience that the center offers. Starting at 3 pm at the BCCN, the programs will be introduced with short talks. There will also be the opportunity to meet current and former students of the program. At 5 pm there will be a scientific talk by Johannes Letzkus (Max Planck Institute for Brain Research, Frankfurt).

www.bccn-berlin.de/Calendar/Events/event/?contentId=3667

DZNE Deutsches Zentrum für Neurodegenerative Erkrankungen in der Helmholtz-Gemeinschaft

Bernstein Network Computational Neuroscience

Bernstein Day 2014

On December 18, 2014, Julius Bernstein would have celebrated his 175th birthday. In his honor, we celebrate this year's Bernstein Day on December 18, 2014. Bernstein members organize a number of activities at various locations distributed all over Germany. These range from lectures and film screenings to workshops and courses (see p 17).

But who was the man the Bernstein Network is named after? In 1839, Julius Bernstein was born as the oldest of seven children in Berlin. He took up his medical studies in Wroclaw before returning to Berlin, where he completed his PhD on muscle physiology in invertebrates. The young physiologist then became assistant to Hermann von Helmholtz in Heidelberg. After his habilitation and a short stay in Berlin,Bernstein was appointed professor for physiology at the University of Halle (Saale) in 1873. Here, he worked for almost 40 years. One of its most significant findings is the "membrane theory", in which he identified the semi-permeability of the cell membrane to different ions as a trigger for a potential gradient—the so-called membrane potential.

More information on the events of the Bernstein Day:
www.nncn.de/en/news/events/december-18-bernstein-day-2014

Bernstein Center Berlin
Film screening for high school students: "Schmetterling und Taucherglocke"
followed by a discussion with a stroke and a BCI expert

Bernstein Focus Learning and Bernstein Collaboration in Constance
Talk: Hirnforschung bei Insekten - was wir von Bienen über unser Gehirn lernen können
Speaker: Paul Szyszka
afterwards: lab visits with the opportunity to perform experiments
Organizers: Giovanni Galizia, Christoph Kleineidam

Bernstein Focus Neurotechnology Frankfurt
Talk: *Bernstein Day Lecture*
Speaker: Raoul-Martin Memmesheimer
Workshop "Neural Information Dynamics, Causality and Computation near Criticality",
Software Course: *"Software course on Neural Information Dynamics with TRENTOOL, the Java Information Dynamics Toolkit and MuTE"*
Organizer: Matthias Kaschube

Bernstein Center Freiburg
Bernstein Coordination Site
Interactive talk: "Café Scientifique Nr. 4 – Über das Gehirn und seine Erforschung"
Speaker: Stefan Rotter

Bernstein Facility Simulation and Database Technology in Jülich
Video publications on the Human Brain Project
Web page: www.fz-juelich.de/ias/jsc/bernsteinday
Organizer: Anne Do Lam-Ruschewski

Bernstein Center Göttingen
Bernstein Focus Neurotechnology Göttingen
Public lecture: "Neural Processing of Continuous Sensory Streams"
Speaker: Robert Gütig

Bernstein Center Munich
Talk: *Talking Science - Julius Bernstein Honorary Lecture*
Speaker: Ed Boyden (Massachusetts Institute of Technology (MIT), USA)

Bernstein Center Tübingen
Film screening: "Auf der Suche nach dem Gedächtnis"
Introduction: Jan Benda

Dates

Date	Title	Organization	URL
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
Dec. 1, 2014, Berlin	Symposium: Sensory computation in neural systems	Bernstein Center Berlin	www.bccn-berlin.de/Calendar/Events/event/?contentId=3561
Dec. 8–19, 2014, Freiburg	Course: Simulation of biological neuronal networks	Cooperation between Bernstein Center Freiburg and Simulation Laboratory Neuroscience-Bernstein Facility for Simulation and Database Technology at Forschungszentrum Jülich	www.bcf.uni-freiburg.de/teaching-and-training/contents/bnn2014-15
Dec. 12, 2014, Montreal, Canada	NIPS Workshop on large scale optical physiology: From data-acquisition to models of neural coding	F. Diego, J. Freeman, J. Macke (BCCN Tübingen), I. Memming Park, E. Pnevmatikakis	http://hci.iwr.uni-heidelberg.de//Staff/fdiego/LargeScaleOpticalPhysiology
Dec. 18, 2014, throughout Germany	Bernstein Day 2014—with events organized by the Bernstein Network on the occasion of Julius Bernstein‘s 175th birthday	Bernstein Network	www.nncn.de/en/news/events/december-18-bernstein-day-2014
Jan. 14, 2015, Berlin	Berstein Center Berlin information day about Computational Neuroscience Graduate Programs	Bernstein Center Berlin	www.bccn-berlin.de/Calendar/Events/event/?contentId=3667
Feb. 23–27, 2015, Munich	7th G-Node Winter course on neural data analysis	J. Grewe, A. Herz (BCCN Munich, G-Node), T. Wachtler (BCCN Munich, G-Node)	https://portal.g-node.org/dataanalysis-course-2015/doku.php
Mar. 13–15, 2015, Tokyo, Japan	2015 International Clinical Brain-Machine Interface Workshop (CBMI 2015)	N. Birbaumer (BFNT Freiburg-Tübingen), J.L. Contreras-Vidal, L.R. Hochberg, K. Kanasaku, M. Kawato, S.R. Soekadar (BFNT Freiburg-Tübingen)	www.bmi2015.org

Dates

Date	Title	Organization	URL
Mar. 17, 2015, Berlin	Symposium: Neurophysics: Physical approaches to deciphering neuronal information processing within the framework of the 79th Annual Meeting of the DPG (Deutschen Physikalischen Gesellschaft) and DPG Spring Meeting	T. Geisel (BCCN Göttingen), G. Güntherodt	www.nncn.de/en/news/events/symposium-neurophysics
June 8–10, 2015, Antibes – Juan les Pins, France	1st International Conference on Mathematical NeuroScience	W. Stannat (BCCN Berlin) is member of the Program Committee	http://icmns2015.inria.fr

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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