

Bernstein Network Computational Neuroscience

Bernstein Newsletter



Recent Publications

Direct Connection for Orientation – Information Flow – New Type of Computer



Meet the Scientist

Matthias Kaschube



News and Events

Personalia – New D-USA Collaborations – 2nd Phase of the Excellence Initiative – Book: “Monkey Society” – Transcranial Stimulation and EEG – Opening of BCAN



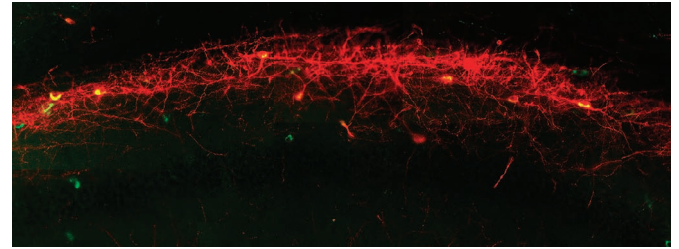
Direct Connection for Orientation

Two brain areas that are considered to be hubs for spatial orientation and spatial memory are directly connected to each other by long branches of inhibitory neurons. This is what scientists working with Hannah Monyer of the Bernstein Center Heidelberg-Mannheim, the German Cancer Research Center, Heidelberg University and the University Hospital Heidelberg have shown. The newly discovered direct connection is thought to contribute to synchronizing the two brain regions and by this to processing spatial impressions.

The so-called hippocampus is a brain region that is central for spatial orientation. Some years ago, British researchers found that London taxi-drivers have characteristic changes in the volume of this brain structure, which, moreover, were the more pronounced the longer the drivers had worked in their profession.

Based on studies that were performed in rodents and nonhuman primates neuroscientists deduced that most sensory input reaches the hippocampus via the entorhinal cortex. The two brain regions are heavily interconnected bidirectionally. “However, until now only excitatory neuronal projections were thought to provide direct connectivity”, says Hannah Monyer. “We have now shown that inhibitory neurons that release the neurotransmitter GABA also form direct links between the two structures and thus contribute to the interaction between the two brain areas.”

Using a new detection method, the researchers were able to visualize the individual neuronal connections and study their functions in detail, by way of introducing a light-sensitive fluorescent protein into the inhibitory GABA neurons in the brain tissue of mice. With the aid of this fluorescent marker, they were able to precisely track the course of the long neuronal processes



Fluorescence image of hippocampal connection neurons: first, the neurons were labeled in green and, afterwards, the light-sensitive protein (red) was injected.

between the two brain areas under the microscope. In addition, they could identify the target cells of the new direct connections. These turned out to be mainly inhibitory interneurons. This type of neuron locally interconnects hundreds of neighboring neurons, thereby setting the pace for bigger areas of the brain.

With laser pulses, the researchers activated the light-sensitive protein in some of the long-range neurons, triggering electrical discharges. At the same time, they observed an inhibition of the target cells. Activation of already a few long-range neurons had a major impact on the overall population. This is because their target cells, the interneurons, in turn—like conductors—can synchronize large ensembles of neurons. Figuratively speaking, the newly discovered long-range inhibitory neurons coordinate the “conductor cells”, which in turn each lead their own orchestra. These results obtained in tissue slices are now being verified in living mice.

Text: Deutsches Krebsforschungszentrum (mod.)

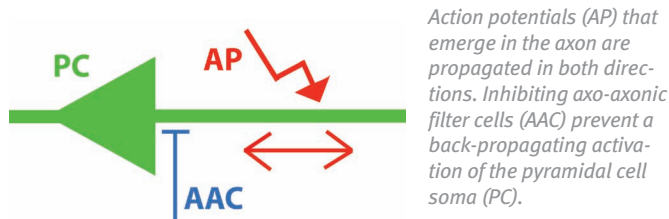
[Melzer S*, Michael M*, Caputi A*, Eliava M, Fuchs E C, Whittington M A, Monyer H \(2012\): Long-range-projecting GABAergic neurons modulate inhibition in hippocampus and entorhinal cortex. Science 335: 6075 \(*equal contribution\)](#)



Information Flow – no One-Way Street

A longstanding question in brain research is how information is processed in the brain. Neuroscientists at the Institute of Neurophysiology at the Charité – Universitätsmedizin Berlin, Bernstein Center Berlin, Cluster of Excellence NeuroCure, and University of Newcastle have made a contribution towards answering this question. In a new study, they have shown that signals are generated not only in the cell body of nerve cells, but also in their output extension, the axon. A specific filter cell regulates signal propagation.

Until now it has been assumed that information flow in nerve cells proceeds along a “one-way street”. Electrical impulses are initiated at the cell body and propagate along the axon to the next neuron, where they are received by extensions, the dendrites, that act as antennae. However, this model needs to be revised, as has been demonstrated by a team around the researchers Tengis Gloveli, Tamar Dugladze and Dietmar Schmitz. They discovered that signals can also be initiated in axons, i.e. outside the cell body. This happens during highly synchronous neuronal activity as, for example, in a state of heightened attention. Moreover, these axonally generated signals flow bi-directionally and represent a new principle of information processing: on the one hand, impulses propagate from their origin towards other nerve cells; on the other hand, the signals also backpropagate towards the cell body, i.e. in the “wrong direction” against the one-way street. These backpropagating signals bear the danger to overexcite the cells.



However, the researchers found that, under normal conditions, backpropagating signals do not reach the cell body. The reason for this is a natural filter that prevents these signals from passing. “Axo-axonic cells, an inhibitory cell type, regulate signal propagation and thus occupy an outstanding strategic position,” explains Tamar Dugladze. Through the filter function, these cells allow signals initiated at the cell body to pass, but suppress backpropagating impulses generated in the axon. By this means, excessive activation of the cell body is prevented. In experiments, the scientists could show that when this filter function is deactivated, backpropagating signals are allowed to pass, resulting in higher cell activation.

These filter cells can become damaged in various neurological diseases. The resulting misregulation of signal flow, in turn, has fatal effects on information processing in the brain. “Results of this study shed new light on the central question of how signals are processed in the brain. In addition, these findings could help us better understand the development and progress of neuronal diseases such as epilepsy, which involves excessive hypersynchronous activity of large sets of neurons. This knowledge could open up new therapeutic approaches”, says Tengis Gloveli. The neuroscientists will therefore focus their future research on both basic understanding of the mechanisms of signal flow in the nervous system, and the relevance of these mechanisms in the genesis of epilepsy.

Text: Charite – Universitätsmedizin Berlin

Dugladze T, Schmitz D, Whittington M A, Vida I, Gloveli T (2012): Segregation of axonal and somatic activity during fast network oscillations. *Science* 336: 6087



Computing saddles

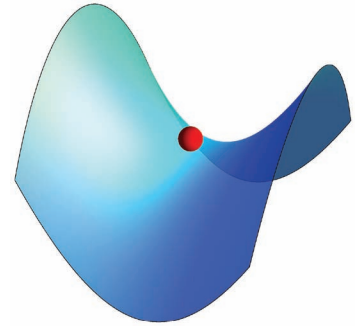
Processing information using oscillating elements such as pendulums or lasers – scientists at the Max Planck Institute for Dynamics and Self-Organization and the Bernstein Center Göttingen have now shown with their *complex network computer* that this could work in principle. Their completely new approach shows how computers of the future may work. So far, the system can only be simulated, but constructing the actual hardware is under way. Already, the new principle outperforms standard computers in certain sorting tasks and a robot using a *complex network computer* as its “brain” even found its way through an obstacle course.

Common computers perform arithmetic operations such as addition and division using two states: 0 and 1. Scientists working with Marc Timme and Fabio Schittler Neves have now developed a completely different system. “In principle, all oscillating systems qualify as building blocks for *complex network computers*,” says Timme. “The simplest example would be a pendulum,” he adds. If several pendulums are connected to each other by a spring, they show dynamic behavior that can be used to process data.

So-called saddle states are key to this behavior. In these states, the system as a whole is stable in some respect, and unstable in others. “Imagine a ball in the trough of a horse saddle,” says Timme. “If you deflect the ball exactly in parallel to the horse’s back, it rolls back into the trough. If the ball is pushed perpendicularly to the horse’s back, though, it falls down (depending on the force’s direction, to one or the other side). In these directions, the state is unstable.” In the case of coupled pendulums, a saddle point is a specific state in which certain groups of pendulums move synchronously.

Coupled oscillating systems often exhibit many saddle points between which they can alternate, depending on external influences. The final trajectory depends on the input signal.

Depending on the deviation, the ball either returns to its former state or falls into one of two other states, both also saddle points.



“Each input may be composed of several sub-signals,” explains Schittler Neves. In the case of a group of coupled swinging pendulums, a sub-signal could consist of a small nudge applied to a single pendulum. The relative strengths of these sub-signals determine which new saddle-point the system will approach. “Thus, the new state provides information about the relative sizes of the sub-signals,” says Timme. In their most recent publication, the researchers were able to show that generally all logical operations such as addition, multiplication and negation can be generated by a *complex network computer*.

Already now, the system can solve tasks like rough number sorting much more efficiently than conventional computers do. In a first practical application, a simple robot successfully navigated through an arena with obstacles. Outputs of sensors provided the input signals to the *complex network computer*. “We are still far from building a powerful computer in the true sense of the word,” says Timme. To date, the new principle can only be simulated. But the construction of real hardware is under way. “We have shown that the idea does in principle work,” Timme adds. The current status of their computer is thus comparable to the beginnings of quantum computer research, from which scientists today expect major advances in computer technology.

Text: MPI f. Dyn. a. Self-Org., BCOS

Schittler Neves F, Timme M (2012): Computation by switching in complex networks of states. *Phys. Rev. Lett.* 109: 018701, [dx.doi.org/10.1103/PhysRevLett.109.018701](https://doi.org/10.1103/PhysRevLett.109.018701)



MEET THE SCIENTIST

Matthias Kaschube

How do we sort and process stimuli, why does the brain develop in a certain way and how do cells organize into tissue? It is always the same question that drives Matthias Kaschube: How do structures develop in living systems? Since December 2011, he has been Professor for “Computational Neuroscience/ Computational Vision” at the Institute for Computer Science and Mathematics of the Goethe University and at the Bernstein Focus Neurotechnology (BFNT) Frankfurt and fellow at the Frankfurt Institute for Advanced Studies.

Kaschube first studied philosophy and physics in Frankfurt, before moving to Göttingen after his pre-diploma in physics. “In philosophy, I became very interested in the neuroscience-oriented topics such as perception and free will,” Kaschube explains. “But the very concrete approaches of physics and computer science suited me much better,” he says. It was in the laboratory of Theo Geisel at the Max Planck Institute for Dynamics and Self-Organization and the Bernstein Center Göttingen, that he first came into contact with computational neuroscience. In Geisel’s group and under Fred Wolf’s supervision, he wrote his diploma and PhD thesis, and was subsequently a Bernstein Fellow for one year, before he moved to William Bialek at the Lewis-Sigler Institute for Integrative Genomics, at Princeton University, USA. There he held an independent position as a Lewis-Sigler fellow for five years.

Central to his research is the principle of self-organization. This term describes processes that create order without external influences. Everyday examples are flocks of birds and Mexican waves in soccer stadiums. “Self-organization could play a significant role in linking different stimuli in the brain, for example the fact that we perceive color, shape and movement of an object as a unit,” explains Kaschube.



In collaboration with Göttingen scientists around Fred Wolf and Siegrid Löwel, he succeeded in 2010 in showing that central aspects of the functional structure of the primary visual cortex are very likely neither genetically determined nor shaped through environmental influences, but have developed through self-organization. Most cells in the primary visual cortex are tuned to a small part of the visual field. Many cells specifically react to edges with a certain orientation. In a wide variety of mammals, such as humans, cats, ferrets and tree shrews, such cells build patches of equal orientation preference that are organized around so-called pinwheels (see figure p. 11). Through mathematical models and quantitative analyses of experimental data, they were able to show that these pinwheel patterns are virtually identical in different species, despite the fact that they probably developed completely independently in the course of evolution. Cortical self-organization can explain this structural stability.

Unlike humans and tree shrews, mice—close relatives of primates—show fundamental differences in the organization of the visual system. In mice, this distinctive structural organization cannot be found. The comparison between primates and rodents allows further insight into the organization of the brain: “By studying the structure and data processing in the visual system of different animals with quantitative models, we can better compare them with each other. This allows us to describe both universal principles and to locate very specific adaptations to different visual environments,” says Kaschube.



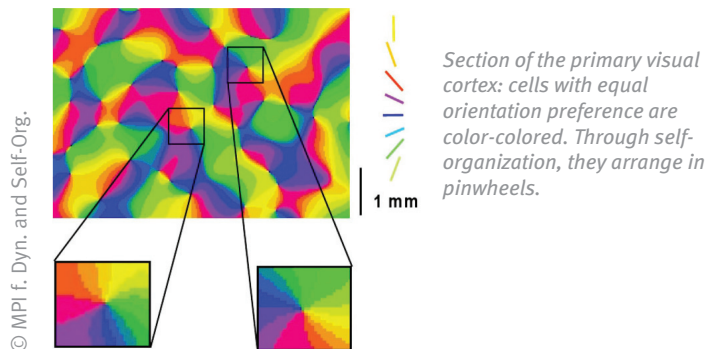
MEET THE SCIENTIST

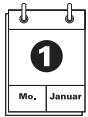
During his research stay in the United States, Kaschube also collaborated closely with Eric Wieschaus, who, in 1995, received the Nobel Prize for his research in developmental biology. “He’s a very inspiring person, always open to unconventional hypotheses and approaches,” says Kaschube about their cooperation. “And I have greatly benefited from the fact that he is very interested in new quantitative methods.” Together with Wieschaus, he created a method to quantitatively compute the development of cell and organ structures from two-dimensional microscopy images of fruit fly embryos. This allows to precisely follow the collective rearrangements of thousands of cells forming body structures. Such exact measurements also make it possible to develop computer models that can potentially help to better investigate the complex processes during early embryonic development.

The Frankfurt scientist will also continue to pursue work that aims at a better quantitative understanding of tissue and organ formation. Since just as for a network of nerve cells, embryonic tissue must be properly structured. Both processes—structure formation and regulation—probably follow similar principles. “This results in conceptually new and theoretically interesting questions,” Kaschube says, “once again we realize that we can learn a lot by looking beyond the boundaries of each discipline.” The principles of complex neurobiological connections in many

cases can be much more easily studied in much simpler systems. A project combining both neuroscience and developmental biology is planned already. Together with Frankfurt developmental biologists, Kaschube wants to mathematically investigate head formation in the nematode *Caenorhabditis elegans*, one of the most important model organisms in biology. In this project, the methods he developed in the United States together with Wieschaus shall be applied. The questions that Kaschube addresses sometimes seem to be quite detached from direct clinical or technical applications. Indeed, for Kaschube, the gain of scientific knowledge is the center of his work: “My work is first and foremost about providing new knowledge for society.” But the step to application is not as big as it sometimes seems.

At the BFNT Frankfurt, Kaschube will collaborate on projects with Visvanathan Ramesh, Christoph von der Malsburg and Jochen Triesch. Here, he will apply the principles of self-organization in the field of autonomous learning and stimulus processing in natural and artificial vision systems. The mathematical models that describe how the visual cortex organizes can now be used to optimize automated image recognition systems. In this context, he wants to examine how stimulus representations spontaneously emerge in recurrent networks—networks in which information can be exchanged within and between different levels in both directions, as it is the case in the cortex. What started with the structuring of orientation-selective areas in the visual cortex is now to be continued on a coding level for various properties. The scientist is still in the process of building up his research group—and is therefore still recruiting. Whether it should be graduate students or postdocs, computer scientists or physicists, “the most important thing is that they enjoy thinking.”





Personalia



Ernst Bamberg (BFNT Göttingen, MPI of Biophysics Frankfurt) was elected new member of the German Academy of Sciences Leopoldina.

www.nncn.de/nachrichten-en/leopoldinabamberg



Benjamin Blankertz (BFNT and TU Berlin) has assumed the W3 professorship “Neurotechnology” at Technische Universität Berlin that was established within the framework of BFNT Berlin and with initial funding by BMBF.

www.nncn.de/nachrichten-en/professurblankertz



Alexander Gail (BCCN, BFNT and DPZ Göttingen) in July 2012 assumed the professorship “Sensorimotor Neurosciences and Neuroprosthetics” that is shared between the University of Göttingen and the German Primate Center. The professorship was established within the framework of BCCN Göttingen and with initial funding by BMBF.

www.nncn.de/nachrichten-en/professurgail



Jakob Macke (left) and **Marcel Oberlaender** (both BCCN, CIN and MPI for Biological Cybernetics Tübingen) are new junior research group leaders at Bernstein Center Tübingen. **Jakob Macke** furthermore received the Otto Hahn Medal of the Max Planck

Society for his outstanding doctoral thesis “Population coding in the visual system: Statistical methods and theory”.

www.nncn.de/nachrichten-en/juniorresearchgroups

www.idw-online.de/de/news485740 (in German)



Frank Schaeffel (BCCN and University Tübingen) was awarded the European Vision Award 2012 by the European Vision Institute (EEIG) for especially outstanding contributions in the field of vision research.

www.vision-research.eu/index.php?id=736



Bernhard Schölkopf (BCCN Tübingen, BFNT Freiburg-Tübingen, MPI for Intelligent Systems Tübingen/Stuttgart) received the Academy Prize of the Berlin-Brandenburg Academy of Sciences and Humanities for his outstanding scientific achievements in the field of machine learning.

www.idw-online.de/de/news481927 (in German)



Eberhart Zrenner (BCCN and University Hospital Tübingen) received the prestigious US-American Ludwig von Sallmann Prize for his lifetime achievements in investigating the causes and the development of novel therapies for hereditary blindness-causing retina degeneration.

www.idw-online.de/de/news489567 (in German)



NEWS AND EVENTS

New Call for German-US American Collaborations in CNS



New proposals for German-US-American collaborations are solicited within the funding measure “Germany-USA Collaboration in Computational Neuroscience”. The transnational initiative for supporting collaborative research between Germany and USA is jointly funded by the German Federal Ministry of Education and Research (BMBF) and the National Science Foundation (NSF). Next deadline for applications is November 2nd, 2012.

www.nncn.de/nachrichten-en/dusacollaborationscall

2nd Phase of the Excellence Initiative

Scientists of the Bernstein Network have participated successfully in the second program phase of the German Excellence Initiative, the results of which were published on June 15, 2012. Bernstein scientists are now affiliated with 9 of the 11 “Excellence Universities” and contribute to 9 of the 43 funded Clusters of Excellence and to 8 out of the 45 Graduate Schools.

Of the 8 existing Clusters of Excellence in which Bernstein members were involved, 6 are granted funding for another 5 years. In addition, 3 new clusters succeeded in the contest for new funding:



- The new Freiburg cluster “BrainLinks-BrainTools” will investigate the function of the human brain and develop new interfaces that will allow patients to control technical devices with their nervous system.

www.brainlinks-braintools.uni-freiburg.de



- The new Munich cluster for Systems Neurology (SyNerg) takes an integrative approach towards unravelling the interactions between different pathologies that contribute to the development of neurological diseases.

www.uni-muenchen.de/ueber_die_lm_u/lmu_excellent/cluster/synergy

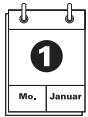


- The new Oldenburg cluster “Hearing4all” deals with models, technology and solutions for diagnostics, restoration and support of hearing.

www.hearingresearch.uni-oldenburg.de

Bernstein scientists also contributed successfully to new training concepts. 8 out of the 9 graduate schools with Bernstein members in their faculty were selected for extended funding.

www.nncn.de/nachrichten-en/bernsteinexinz



NEWS AND EVENTS

New Book: Monkey Society



© Oliver Möst

What distinguishes us from our closest relatives, what connects us, and what do large brains have to do with intelligent behavior? In her book “Monkey Society” (Affengesellschaft), behavioral scientist Julia Fischer (BCCN and German Primate Center, Göttingen) explains in an entertaining and understandable way her research on intelligence, communication and social

behavior of monkeys. Fischer offers the reader insights into the day-to-day research work and describes her personal development as a scientist.

[Julia Fischer: “Affengesellschaft”, Suhrkamp 2012.](#)

[ISBN-13: 978-3518423028](#)

neuroConn Development: Transcranial Stimulation with EEG



The Ilmenau company neuroConn GmbH, who collaborated with Helmut Buchner (Recklinghausen), Walter Paulus (BCCN, BFNT and University Medicine Göttingen) and Gunter Knoll (Kassel) within the Bernstein collaboration “Transcranial Stimulation”, has developed a technique that allows faithful EEG recording during transcranial stimulation using weak alternating currents (tACS) or random noise currents (tRNS). The new technology is already being employed in the company’s new generation of stimulators.

www.nncn.de/nachrichten-en/neuroconn

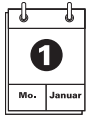
Symposium and BCAN Opening



On October 29-31, 2012, the symposium “Neural Computation: From Perception to Cognitive Function” will take place in Berlin. Subsequently, the “Berlin Center for Advanced Neuroimaging” (BCAN), that was established with support by BMBF and DFG

(amongst others) will be ceremonially opened on October 31st.

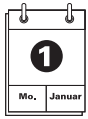
www.bccn-berlin.de/symposium-2012



NEWS AND EVENTS

Upcoming Events

Date	Title	Organizers	URL
Sept. 2-7, 2012 Kiel	Summer School: Advanced Scientific Programming in Python	Z. Jedrzejewski-Szmek (G-Node), T. Zito (BCCN Berlin, G-Node), C. T. Steigies, C. Drews	http://python.g-node.org
Sept. 3-7, 2012 Göttingen	10th Summer Course on Computational Neuroscience (hosted by BCCN Göttingen)	D. Hofmann, A. Palmigiano, M. Puelma-Touzel	www.bccn-goettingen.de/events/cns-course
Sept. 3-7, 2012 Bochum	Summer School: Neuronal Dynamics Approaches to Cognitive Robotics	E. Bicho, W. Erlhagen, G. Schöner (BFNL Learning Behavioral Models, BGCN Bochum)	www.robotics-school.org
Sept. 6-8, 2012 Heidelberg	2nd Workshop on Computational Properties of Prefrontal Cortex: Prefrontal-Hippocampal Interactions	BCCN Heidelberg-Mannheim	www.nncn.de/termine-en/ws2prefrontalcortex
Sept. 9-12, 2012 Klosterneuburg Austria	Conference: Sensory Coding & Natural Environment 2012	G. Tkacik, M. Bethge (BPCN 2006, BCCN Tübingen), E. Schneidman	www.ist.ac.at/scne2012
Sept. 10-12, 2012 Munich	5th INCF Congress of Neuroinformatics	INCF, A. Herz & T. Wachtler-Kulla (BCCN Munich, G-Node)	www.neuroinformatics2012.org
Sept. 12-14, 2012 Munich	Bernstein Conference 2012	A. Herz & T. Wachtler-Kulla (BCCN Munich, G-Node)	www.bccn2012.de
Sept. 16-19, 2012 Jena	BMT 2012: 46th DGBMT Annual Meeting	H. Witte & J. Haueisen (BGCN Jena), A. Voss	http://conference.vde.com/bmt-2012
Sept. 17-19, 2012 Berlin	BBCI Workshop 2012 on Advances in Neurotechnology	Chairs: B. Blankertz & K.-R. Müller (BFNT & BCCN Berlin)	http://bbci12.ml.tu-berlin.de
Sept. 18-21, 2012 Castro Urdiales Spain	Conference: Dynamical Systems on Random Graphs	J. Bolte, D. Mugnolo, O. Post, S. Rotter (Bernstein Center Freiburg)	www.uni-ulm.de/dsrg2012
Sept. 20-28 2012 Berlin	Summer School: Brain-Computer Interfacing and Neurotechnology	K.-R. Müller (BFNT & BCCN Berlin, BCOL Neurovascular Coupling)	http://bbci12.ml.tu-berlin.de/summerschool
Oct. 7-12, 2012 Freiburg	BCF/NWG Course: Analysis and Models in Neurophysiology	S. Rotter & U. Egert & A. Aertsen & J. Kirsch (Bernstein Center Freiburg), S. Grün (BCCN Berlin, D-J Cooperation)	www.bcf.uni-freiburg.de/events/conferences-workshops/20121007-nwgcourse



NEWS AND EVENTS

Upcoming Events

Date	Title	Organizers	URL
Oct. 8-9, 2012 Göttingen	Conference: Cellular Mechanisms of Sensory Processing	M. Göpfert (BCCN Göttingen), S. Löwel (BFNT Göttingen), T. Gollisch (BCCN Munich), T. Moser (BCCN & BFNT Göttingen), J. Staiger (BFNT Freiburg-Tübingen)	www.sensoryprocessingworkshop.uni-goettingen.de
Oct. 13-17, 2012 New Orleans, USA	SfN 2012, with Bernstein Information Booth	Society for Neuroscience	www.nncn.de/termine-en/sfn2012
Oct. 29-31, 2012 Berlin	Symposium: „Neural Computation: From Perception to Cognitive Function“ and opening ceremony of the Berlin Center for Advanced Neuroimaging	Research Training Group 1589 “Sensory Computation in Neural Systems”, BCCN Berlin and Berlin Center for Advanced Neuroimaging	www.bccn-berlin.de/symposium-2012
Mar. 13-16, 2013 Göttingen	NWG 2013, with Bernstein Network Contributions	German Neuroscience Society	www.nncn.de/termine-en/nwg2013
Aug. 25-29, 2013 Bremen	European Conference on Visual Perception	U. Ernst (BPCN 2010, BGCN Bremen), C. Grimsen, D. Wegener	www.nncn.de/termine-en/ecvp2013

The Bernstein Network

Chairman of the Bernstein Project Committee: Andreas Herz (Munich)

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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Title image: Ball at a saddle point. Depending on the deviation, the ball returns to its former state or falls into one of two other states, both also saddle points (see article p. 7).

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