



Bernstein Network for Computational Neuroscience

Bernstein Newsletter



Recent Publications

How Flies Hear – What Bees Smell – How Birds Plan – Loud Noise and Whispers – Stopwatch in the Brain



Meet the Scientist

Andreas Herz



News and Events

Personalia – Measuring Brain Signals – VW Grant – Events

03/2009

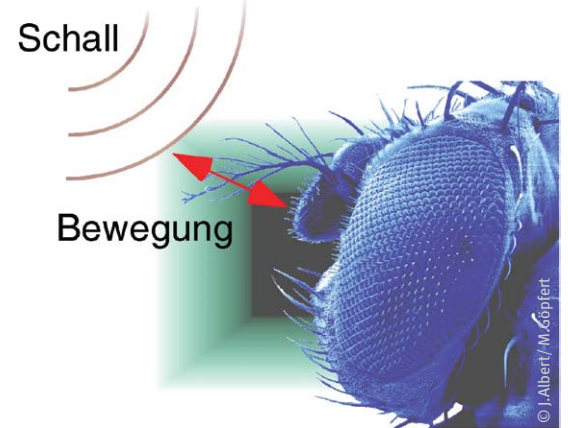


How flies hear

The ears of flies and humans are as different as the two creatures themselves – and yet they have one thing in common: a mechanic amplifier that is particularly good at amplifying low sounds. In collaboration with his colleagues, Martin Göpfert, scientist from the University of Göttingen and the Bernstein Cooperation ‘Information coding’, now showed how this mechanism works, using the example of the fly. Flies hear with their antennae. These are freely accessible for measurements, thus being especially well-suited for analyses.

During the process of hearing, sound waves set a sound receiver in motion – in the case of humans, the eardrum; in the case of flies, the outer segments of the antenna. Downstream sensory cells in the fly’s antenna are stretched by the deflection of the sound receiver. This stretching is coupled with an ion channel in the cell membrane. When the channel opens, charged molecules can flow into the cell, resulting in an electrical impulse – a neuronal signal.

At this point, the mechanic amplifier comes into play. ‘Since the channels are opened directly by a mechanical mechanism and no chemical signaling cascades are interposed, signal amplification must be achieved mechanically, as well,’ says Göpfert. ‘Every sensory perception requires signal amplification, but only during the hearing process, this is achieved mechanically.’ It is still not known what exactly the elastic coupling between the antennal oscillation and the ion channel looks like and where the amplifier intervenes. But now, Göpfert and his colleagues have come a little closer to this secret of nature. They developed a theoretical model, which explains the amplification and verified it through refined measurements on the flies antennae. The scientists use sophisticated techniques to exert force on the antenna and measure its tiny deflection of less than 10 nanometers – a ten-



Flies hear with their antennae

thousandth of a hair’s breadth. ‘We show that our model exactly describes the activity of the amplifier,’ says Göpfert.

In the model, the coupling between receiver and channel is represented by a spring. When the spring is extended by the antenna’s movement, the ion channels open. Thereby, the spring relaxes and the movement is facilitated. This, in turn, retroacts on the antenna – it swings out wider as the channels open. The system needs energy to close the channels again and to stretch the spring. The scientists were able to show that this is realized by means of small movement motors. ‘Through the interaction between motors and channels, energy is pumped into the system, thus amplifying the antenna’s oscillations,’ explains Göpfert.

In further experiments, the scientists were able to show that the motors work most effectively with low sounds, where a maximal amplification is achieved. If the ear is stimulated at a certain frequency, the sensitivity to this frequency is increased with each oscillation. Thus, flies – just like us – are able to distinguish very well between different frequencies, even when sounds are low. ‘Our experiments demonstrate how the interaction between ion channels and molecular motors shapes the behavior of the whole ear,’ says Göpfert.

Source: Nadrowski B, Albert JT, Göpfert MC. *Curr. Biol.* 2008 Sep 23;18(18):1365-72.



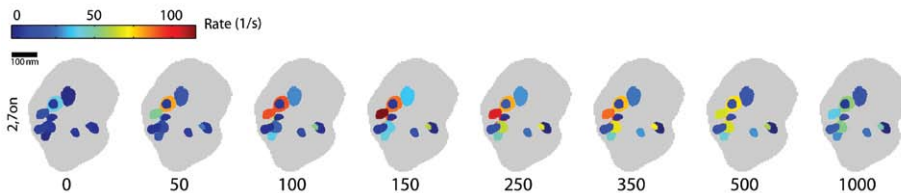
What does the bee smell?

Bees have a well-developed olfactory sense, which they use not only for locating food sources, but also for communication. For example, they share information about brood care using self-produced odors. Whereas self-produced communication signals comprise single or only very few chemical components, the odors of flowers or other environmental signals typically represent a complex mixture of odors. ‘For the bee it could be relevant to distinguish quickly between these two odor classes,’ says Martin Nawrot from the Bernstein Center for Computational Neuroscience and the Free University of Berlin. Together with Randolph Menzel and Sabine Krofczik – both of them scientists at the same research institutions – he was now able to show how such a classification is accomplished at a neuronal level.

Bees smell with their antennae. Neurons in the antennae are stimulated by odors, i.e. they become electrically active, and transmit this information to the antennal lobe in the brain, the first relay level of olfactory information. All information that is processed in the antennal lobe then reaches higher brain regions via a limited number of approximately 900 projection neurons. ‘These neurons must thus contain all the information that is important to the bee,’ explains Nawrot. These neurons have been examined by Sabine Krofczik in Randolph Menzel’s experimental working group by means of complex electrical recordings.

First of all, the scientists examined the neurons’ reaction to single odor components. They found out that the neurons use a spatial as well as a temporal ‘code’ for decoding odors. A ‘temporal’ code manifests itself in the sequence of neuronal activation. ‘Within a fraction of a second, the neurons are turned on like little lamps,’ explains Nawrot, ‘it has been recently discovered that the animals are indeed able to recognize learned odors that quickly.’ But also the extent with which neurons react to the odor – the light intensity pattern of the lamps – provides information about odor identity. This ‘spatial’ signal lasts longer and, in addition, it can encode the odor’s concentration: if all neurons generally show a stronger reaction, the concentration is higher.

But how do neurons react to odor mixtures? Here, the scientists have observed clear differences between different types of projection neurons. The m-projection neurons’ reaction to an odor mixture is approximately as strong as their strongest response to the single components. ‘Thus, the whole mixture of components is represented in the combination of m-neurons,’ says Nawrot. The activity of l-projection neurons, on the other hand, is typically suppressed in the presence of more than just one odor component. ‘The different processing in the l-pathway and in the m-pathways reveals that, in the bee’s brain, odors are either assigned to the group of simple odors or to the group of complex mixtures,’ Nawrot explains the result, ‘bees could thus immediately distinguish between a communication signal and an environmental signal, for example a food source.’



[Krofczik S, Menzel R & Nawrot MP. *Frontiers in Computational Neuroscience* 2:9 \(2009\)](#)

Spatio-temporal pattern of the neuronal reaction. The activity of the projection neurons (color coded) is projected back onto the antennal lobe.



How birds learn to plan their actions

Experience teaches us to associate objects with meaning – we learn that a stop sign or a red traffic light mean that we have to stop. This example shows that objects of different visual appearance often have a similar ‘behavioral relevance’ – as it is called by experts. The ability to classify objects according to behaviorally relevant criteria is an essential prerequisite for goal-directed behavior. Scientists around Janina Kirsch and Onur Güntürkün from the Ruhr University Bochum, together with Ad Aertsen from the Bernstein Center and the University of Freiburg, have studied how behaviorally relevant categories evolve in the brain of birds during the learning process.

In their experiments the scientists trained pigeons to respond to images that were presented to them with a certain behavioral pattern. More precisely: when the birds saw the shape of a heart or a lightning they were supposed to ‘mandibulate’, i. e. to move the beak. If they solved the task correctly, they received a reward. When they saw a triangle or a cross, however, they only received a reward if they did not move their beak. During the experiments, the scientists recorded the activity of individual nerve cells in the ‘nidopallium caudolaterale’ (NCL) of the birds, a brain region that is assumed to be responsible for the planning of actions and so fulfils a similar function as the ‘prefrontal cortex’ of mammals and humans.

The scientists investigated two pigeons, a ‘beginner’ pigeon and an ‘experienced’ pigeon that had more practice in solving the tasks. In the NCL of both pigeons, the majority of neurons responded according to the behavior that was indicated by the images. For example, they only responded in trials in which the animal was supposed to mandibulate – no matter whether a heart



© Oliver Wrobel

Pigeon with brain (relative location).

or a lightning was shown. Thus, in this brain region information is represented according to behaviorally relevant criteria.

But neurons of the beginner animal and the experienced animal differed both with regard to the precision in differentiation as well as to the timing of their response. The cells of the beginner pigeon mostly responded much later in a trial than those of the experienced animal – namely only when the reward was received. ‘The animal interprets its behavior in retrospect and its neurons respond accordingly,’ Kirsch explains these observations. ‘In contrast, the experienced animal knows already upon presentation of the image what behavioral instruction it contains. So, already at this point, the cells respond according to the behavioral categories.’ The results contain important hints on how the meaning of objects and images is learned and represented in the brain of birds.

Source : Kirsch JA, Vlachos I, Hausmann M, Rose J, Yim MY, Aertsen A & Güntürkün O. Behav Brain Res. 2009 Mar 2;198(1):214-23

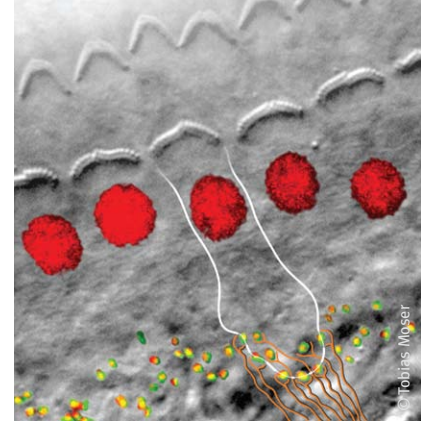


Between loud noise and whispers

The human ear is capable of perceiving an enormous spectrum of sound volumes. The noise of a starting jumbo jet, for example, creates a pressure on the eardrum that is a hundred thousand times greater than that caused by the humming of a mosquito. Nevertheless, we can hear both sounds – albeit not at the same time. How does the ear manage to cover such a wide volume range? Scientists of the University of Göttingen Medical School and Bernstein Center for Computational Neuroscience, took a closer look at an underlying mechanism. The secret apparently lies in how the small hair cells of the inner ear pass on signals to the downstream nerve fibers.

During hearing, sound waves initially cause the eardrum to oscillate. These movements are then passed on inside the ear as a pressure wave and, finally, set in motion tiny hairs on so-called hair cells, the sensory cells of the inner ear. These cells convert the pressure induced oscillations of the hairs into electrical nerve impulses. Each hair cell contacts up to 20 downstream nerve fibers, whose task is to convey the signals towards the brain. Depending on the sound volume, the hair cell activates a varying number of these downstream nerve fibers. The transmission efficiency at the contact site between hair cell and nerve fiber is of crucial importance: it differs from contact site to contact site. As a consequence, some downstream nerve fibers already react to sounds at low volumes, while others only react to loud sounds.

The Göttingen scientists have investigated the exact mechanism of how the hair cells differentially activate nerve fibers, using the mouse inner ear as a model. They were able to unravel a mechanism that is quite unusual for nerve cells. During the deflection of the hairs of a hair cell, the electrical potential across the cell's membrane changes – and the louder the sound,



Microscopy picture of hair cells in the inner ear. A hair cell and its contacts with nerve fibers is schematically emphasized.

the stronger the change. This change in membrane potential leads to the opening of voltage-gated calcium channels at the contact sites to the downstream nerve fibers. Calcium can then flow into the interior of the cell, triggering signal transmission from the hair cell to downstream nerve fibers. The Göttingen scientists were able to show that the amount of calcium influx varies between different contact sites of the hair cell, even though all calcium channels receive the same signal, i.e. are controlled by the same membrane potential. ‘These differences could explain why some contact sites already transmit weak signals, while others are only activated by stronger signals,’ says Moser, the teamleader.

But how do these differences in calcium influx arise? In their experiments, the scientists could show that there are two reasons: Firstly, the number of calcium channels differs from contact site to contact site. Secondly, at different contact sites, the calcium channels show a different sensitivity to the imposed membrane potential and thus, in effect, to the sound volume. ‘Hence, the hair cell unequally equips its contact sites with calcium channels in order to activate downstream nerve fibers to different extents, thus being able to notify the brain about a mosquito as well as a jumbo jet,’ the scientists explain the result. They will now investigate the mechanism behind the observed differences in number and gating behavior of the channels in more detail.

[Frank T, Khimich D, Neef A. & Moser T. PNAS, online 25.02.09](#)



The stopwatch in the brain

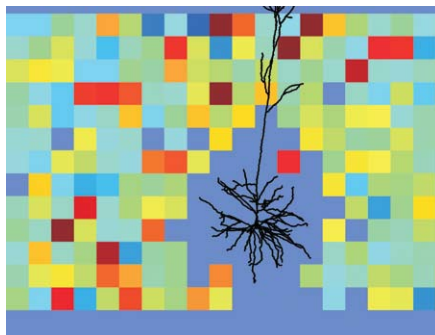
The brain is a highly complex information processing system. Whenever we see, hear or remember, information is transmitted from nerve cell to nerve cell in form of electrical signals – only in this way can we recognize images and understand language. But how is the information coded in the sequence of neuronal impulses? Is the crucial factor the number of impulses or is it rather their exact timing? Scientists around Clemens Boucsein, Bernstein Center for Computational Neuroscience and University of Freiburg, together with Martin Nawrot, Bernstein Center for Computational Neuroscience Berlin, have now addressed this central question of brain research in more detail. They showed: neuronal cells react with greater temporal precision than previously expected.

All neuronal cells transmit information as a sequence of electrical impulses. But the way in which they code information in these signals and how this information is read out by downstream cells differs considerably from cell to cell. Some sensory cells and neurons that activate muscles use a so called ‘rate code’: the more impulses they send per time interval, the brighter the light, louder the sound or stronger the evoked muscle contraction. Other cells, in contrast, use a ‘temporal code’: it is not the number of impulses that matters, but rather their exact timing. It is crucial

whether a cell sends an impulse a few milliseconds before or after another cell. Boucsein and his colleagues investigated which of the two strategies is used by cells in the cortex of the brain.

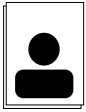
Every cell in the cortex receives many signals from upstream cells. If these cells would use a temporal code, they would also require the ability to respond to these upstream signals with high temporal precision. To test this, Boucsein and his colleagues used a new method developed in their laboratory. In a tissue slice, they measured the electrical activity of a cell, while at the same time activating its upstream cells in a precisely defined temporal sequence. To achieve this, they use a chemical component, which is released under the influence of light and which then stimulates the cells. With a laser and a mirror system, upstream cells are repeatedly switched on in the exact same temporal sequence. ‘We were surprised that the downstream cells react in such a reproducible and temporally precise manner to the sequence of upstream signals,’ says Boucsein. This is all but self-evident. Every signal of the upstream cell needs to be transported along far reaching cellular extensions, transferred to the downstream cell and again transported along this cell’s extensions to the cell body. All these processes could – in theory – lead to temporal imprecision. The fact that the cells nonetheless react so accurately shows that they are literally tailored for the use of a temporal code. If cells in the cortex would instead use a rate code, they would, according to these results, react in an unreliable manner.

Nawrot MP, Schnepel P, Aertsen A, Boucsein C. *Front Neural Circuits*. 2009;3:1. Epub 2009 Feb 10.



© Clemens Boucsein

The strength of the reaction of a downstream cell (black) to the activation of upstream cells in different regions of a tissue slice is shown color coded. Red: strong, blue: weak activation



MEET THE SCIENTIST

Andreas Herz

What can Computational Neuroscience achieve?

To see and hear, light and sound must be translated into nerve signals and processed by the brain: all information that we obtain about the environment is contained in the electrical activity of the nerve cells. But how do these nerve cells – also referred to as neurons – encode this information? How well, for example, are acoustic stimuli reflected in neuronal response patterns, and which properties of the cells determine their response? Together with his group, Andreas Herz, until 2008 coordinator of the Bernstein Center Berlin and now holding the same position in Munich, found answers to some of these questions – by analyzing a very simple model system, the auditory system of the grasshopper.

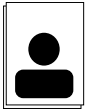
‘It was a winding road full of coincidences,’ says Herz when asked what had given him – as a physicist – the idea to work on grasshoppers. When he started his doctorate in 1987, theoretical physicists had just made some major progress: By means of highly reduced models, they had successfully explained how large neuronal assemblies manage to store sensory stimulus patterns. This set the course for Herz’s doctoral thesis with Leo van Hemmen, where he provided an explanation for how such networks can also learn sequences of patterns and recognize them in an associative way – whether seeing or hearing, each perception is based on a temporal sequence of elementary sensations.

Afterwards, as a postdoc with John Hopfield at Caltech, Herz investigated model neurons that integrate input signals up to a certain threshold value and then discharge in a short impulse. The resulting ‘pulse-coupled’ networks can be directly compared to the dynamics of earthquakes. Here, as well, tensions are slowly built up before there is a quick discharge. ‘From a mathematical point of view, our results were quite fascinating; regarding the



models’ biological relevance, however, I was highly disappointed,’ says Herz. Small changes in parameters, the exact values of which are not even known, led from properties that are typical for neuronal assemblies to those of earthquakes, and vice versa. The models may thus provide predictions that are completely wrong – even worse: you may be given the ‘correct’ results despite having started from several incorrect assumptions. This finding caused Herz to turn away from models of large networks and instead focus on simple single-neuron models. In particular, he and his group study models that are described by parameter combinations that can be measured in individual neurons and do not require any population data. In 1996, as new professor at Humboldt-Universität zu Berlin, he started to investigate the auditory system of the grasshopper. One important reason was the nearby laboratory of grasshopper researcher Bernhard Ronacher. The resulting cooperation led to many new insights and is still going on.

In order to understand how an acoustic signal and the resulting neuronal activity are connected, scientists must compare the two again and again. In the group of Andreas Herz, the grasshopper’s ear was taken as an example to develop procedures, which automate this process and which are, by now, also applied in other areas of neurophysiology. In a feedback system, the neuronal response to a sensory stimulus is analyzed during the ongoing experiment, and – according to the result of the analysis – a new stimulus is created and immediately applied. This requires computer algorithms that communicate very quickly with experimental hardware, a special field of Bernstein Award winner Jan Benda. Together with Christian



MEET THE SCIENTIST

Machens, now professor at the Ecole Normale Supérieure in Paris, Herz used this method to determine the acoustic stimuli to which the grasshopper's neurons react in a particularly reliable way. The scientists have shown that the auditory system of the grasshopper is not optimized for sensory stimuli that occur most frequently in nature, but rather for those that are most important for the behavior of the animal – their own singing.

As a doctoral candidate of Andreas Herz, Tim Gollisch, today leader of a Max Planck Research Group at the MPI for Neurobiology in Munich, explored the question of how the acoustic stimulus is translated into an electrical signal in the grasshopper's auditory system and described the single steps quantitatively. He demonstrated that the eardrum only oscillates twice or three times before it comes to rest. At similar speed, the nerve cell breaks down biochemical signals that transmit information. Together, both processes enable the ear to process acoustic signals quickly and to react to new events without delay.

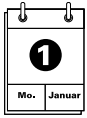
Grasshoppers are not the only research topic Herz is interested in. One other system is the entorhinal cortex – a brain structure that is important for storing information. By means of simple phenomenological models, Herz and his colleagues, amongst others Bernstein Award winner Susanne Schreiber, were able to show that activity patterns of individual cells can be predicted with great precision from the properties of the cell in its resting state.

A model is only as good as its predictive power: 'Progress in Computational Neuroscience can only be achieved by questioning models as soon as they fail to reflect new data,' says Herz. In order to enable neuroscientists to approach this goal jointly and as efficiently as possible, the 'International Neuroinformatics Coordinating Facility' (INCF) was founded in 2005. The Facility's 'National Node' in Germany ('G-Node') is supported by the Federal



Ministry of Education and Research (BMBF) and coordinated by Herz. The goal of 'G-Node' is to advance the exchange of methods and data. This will be achieved by standardizing data formats, by providing analysis methods and by making young scientists familiar with the advantages of this new science culture at an early stage. During the previous project 'Neuroinf' (also led by Herz), valuable neuroinformatics experience was gained, which is now further developed on INCF level. This was one of the reasons why – even prior to the foundation of the Bernstein Centers – the attention of the BMBF was drawn to Germany's potential in the field of theoretical neurosciences.

Addressing quantitative questions is only possible through modelling and mathematical understanding. How much information is contained in a neuronal signal? Which sensory stimuli cause a neuron to generate an impulse? 'Models are always reduced and thus incomplete images of nature,' says Herz. 'However, if we try to keep a model as simple as possible and if the model, nevertheless, predicts the neural behavior, we can be quite sure that we have understood some basic principles.' According to Herz, complex models, on the other hand, involve far more parameters than can be reliably derived from experimental data, thus falsely suggesting an understanding that cannot stand up to critical examination. 'Especially as theorists, we should not be seduced to rashly set up new hypotheses, which may seem attractive at first sight, but which are not really supported experimentally. For the long-term development of the neurosciences, it seems more important to me to question established ideas and to thereby foster the solid foundation of neurosciences. This is the only way how we can – step by step – decode the functioning of the brain.'



Personalia



Theo Geisel, Coordinator of the Bernstein Center Göttingen, Professor at the University of Göttingen and Managing Director of the Max Planck Institute for Dynamics und Self-Organization, will receive the Gentner-Kastler-Preis of the Deutsche Physikalische Gesellschaft and the Société Française de Physique for his outstanding contributions in the field of non-linear dynamics.

Geisel applies the theory of non-linear dynamics, commonly known as chaos-theory, to quite a diverse set of complex systems: Amongst other topics, he investigates the chaotic transport in semiconductor nanostructures, the functioning of the brain and the spread of epidemics.

Source: MPI f. Dynamics and Self-Organization
<http://www.ds.mpg.de/Aktuell/pr/20081212> (in German)



Peter Jonas, member of the Bernstein Center Freiburg and Director at the Institute of Physiology at the University of Freiburg, will be awarded the Adolf-Fick-Preis of the Physikalisch-Medizinische Gesellschaft. The prize is considered to be the most renowned award in physiology in the German-speaking area and includes 10,000 euros.

In his outstanding work, Jonas investigates how nerve cells in brain networks communicate with each other. His major focus is on the hippocampus – a part of the cerebrum that plays a major role in learning and is responsible for complex memory capacities.

Source: Universität Freiburg
<http://idw-online.de/pages/de/news301259>

Nicholas Lesica, scientist at the Bernstein Center in München, will establish and head an Emmy Noether Research Group at the Biocenter of the Ludwig Maximilians University Munich. The funding program of the German Research Foundation supports outstanding young researchers in achieving independence at an early stage of their scientific careers. For three years, Lesica has worked as a postdoc in the group of Benedikt Grothe.

As a group leader – as previously as a postdoc – Lesica addresses the processing of sounds in the brain. Taking advantage of recent advances in experimental technology, Lesica will investigate the brain's ability to process even complex sounds like human speech.

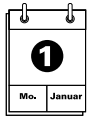
Source: LMU; http://www.uni-muenchen.de/aktuelles/news/forschung/emmy_noether.html (in German)

Measuring brain signals without goo

On December 9, 2008, scientists around Benjamin Blankertz and Klaus-Robert Müller, Fraunhofer Institute for Computer Architecture and Software Technology FIRST, presented the first prototype for a dry electroencephalogram (EEG) on the Neural Information Processing Systems Conference in Vancouver, Canada. The scientists are members of the Bernstein Center and at the Technical University Berlin.

Before measuring can be undertaken, ordinary EEG devices have to be mounted on the patients head in a lengthy, time-consuming process. The single electrodes have to be filled with electrolyte gel to achieve electrical contact with the scalp. Setting up such a device takes about 30 minutes. The scientists now present an alternative that shortens the process to about two minutes. For this purpose, they constructed a flexible helmet with multiple electrode pins and one reference electrode.

Source: Fraunhofer FIRST
http://www.first.fraunhofer.de/press.release/dry_cap



NEWS AND EVENTS

VW-grant for modelling complex systems

Within its Initiative for Modelling and Simulation of Complex Systems, the Volkswagenstiftung has granted more than 400.000 Euro for the continuation of the project 'Rate theory for driven complex biosystems' conducted by Peter Hänggi, University of Augsburg and Lutz Schimansky-Geier, Bernstein Center and Humboldt-Universität zu Berlin. The project concerns computer simulation of neuronal signal processing and translocation processes of biomolecules.

Source: VolkswagenStiftung

<http://idw-online.de/pages/de/news293644>

Bernstein Conference

This year, the annual 'Bernstein Conference on Computational Neuroscience' (previously: 'Bernstein Symposium Computational

Neuroscience') will be organized by the Bernstein Focus Neurotechnology Frankfurt. The conference will take a major step towards further internationalization, expecting around 300 participants in total. **Further information:** <http://bccn2009.org/>

G-Node Winter Course

From January 26-30, 2009 the first Winter Course of the 'German Neuroinformatics Node' (G-Node) took place in Munich. The course is planned as an annual event and offers hands-on experience with neural data analysis for PhD students and young postdocs. It was organized by Martin Nawrot (BCCN Berlin), further faculty were Clemens Boucsein (BCCN Freiburg), Alex Loebel (LMU Munich) and Thomas Wachtler (G-Node). G-Node promotes the exchange of data in the neurosciences, provides analysis methods and offers regular teaching and training to make young scientists familiar with different neuroscience tools.

Further information: <http://www.g-node.org/Teaching/>

Time, Place	Event	Organizers	Link
25. March, Göttingen	Inauguration of the Bernstein Fokus Neurotechnologie	F. Wörgötter, T. Niemann (BCCN /BFNT Göttingen)	
25.-29. March, Göttingen	8th Meeting of the German Neuroscience Society	M. Bähr, I. Zerr / with symposia organized by scientists of the Bernstein Network	www.nwg-goettingen.de/2009/
22-24 May, Göttingen	Ribbon Synapse Symposium	T. Moser, F. Wolf (BCCN Göttingen), N. Brose	www.rss2009.uni-goettingen.de/
25. - 28. May, Hohenwart	3rd Workshop on Detailed Modelling and Simulation of Signal Processing in Neuron	L. v. Hemmen (BCCN München), G. Wittum (BGCN Heidelberg / Frankfurt)	www.techsim.info/
25.-28.May, Berlin	German-Japanese Workshop	K. Obermayer (BCCN Berlin)	www.nncn.de/termine/japanworkshop/
5. - 8. June, Berlin	13th annual meeting of the Association for the Scientific Study of Consciousness (ASSC)	J.D. Haynes (BCCN Berlin), M. Pauen, & P. Wilken	www.assc13.com/
18.-23. July, Berlin	CNS*2009 - 18th Annual Computational Neuroscience Meeting	U. Ernst (BGCN Bremen), J.D. Haynes (BCCN Berlin), A. Herz (BCCN München)	www.cnsorg.org/2009/
3. - 28. August, Freiburg	14th annual Advanced Course in Computational Neuroscience	N. Brunel, J. Rinzel, P. Latham, Y. Prut / F. Dancoisne (BCCN, Admin. Director)	www.neuroinf.org/courses/EUCOURSE/Fog/
30.Sept. - 2.Oct., Frankfurt	Bernstein Conference on Computational Neuroscience	J. Triesch, Ch. v.d. Malsburg, R. Mester (BFNT Frankfurt)	http://bccn2009.org/

Imprint

Published by:
National Bernstein Network Computational Neuroscience
<http://www.nncn.de>

Text, Editing:
Katrin Weigmann: mail@k-weigmann.de

Translation, English Language Editing:
Meike Höpfner, Simone Cardoso de Oliveira, Katrin Weigmann

Coordination:
Simone Cardoso de Oliveira: info@bcos.uni-freiburg.de,
Dagmar Bergmann-Erb, Maj-Catherine Botheroyd, Florence
Dancoisne, Margret Franke, Tobias Niemann, Gaby Schmitz

Design: newmediamen, Berlin

Layout: Katrin Weigmann

Print: Elch Graphics, Berlin

The Bernstein Network for Computational Neuroscience is funded
by the Federal Ministry of Education and Research (BMBF).

*Title image: Hair cells in the inner ear. Modified
after T. Moser*

Das Bernstein Netzwerk

Bernstein Centers for Computational Neuroscience (BCCN)
Berlin – Coordinators: Prof. Dr. Michael Brecht
Freiburg – Coordinator: Prof. Dr. Ad Aertsen
Göttingen – Coordinator: Prof. Dr. Theo Geisel
Munich – Coordinator: Prof. Dr. Andreas Herz

Bernstein Focus: Neurotechnology (BFNT)
Berlin – Coordinator: Prof. Dr. Klaus-Robert Müller
Frankfurt – Coordinators: Prof. Dr. Christoph von der Malsburg,
Prof. Dr. Jochen Triesch, Prof. Dr. Rudolf Mester
Freiburg/Tübingen – Coordinator: Prof. Dr. Ulrich Egert
Göttingen – Coordinator: Prof. Dr. Florentin Wörgötter

Bernstein Groups for Computational Neuroscience (BGCN)
Bochum – Coordinator: Prof. Dr. Gregor Schöner
Bremen – Coordinator: Prof. Dr. Klaus Pawelzik
Heidelberg – Coordinator: Prof. Dr. Gabriel Wittum
Jena – Coordinator: Prof. Dr. Herbert Witte
Magdeburg – Coordinator: Prof. Dr. Jochen Braun

Bernstein Collaborations for Computational Neuroscience (BCOL)
Berlin-Tübingen, Berlin-Erlangen-Nürnberg-Magdeburg, Berlin-
Gießen-Tübingen, Berlin-Constance, Berlin-Aachen, Freiburg-
Rostock, Freiburg-Tübingen, Göttingen-Jena-Bochum, Göttingen-
Kassel-Ilmenau, Munich-Göttingen, Munich-Stuttgart

Bernstein Award for Computational Neuroscience (BPCN)
Dr. Matthias Bethge (Tübingen), Dr. Jan Benda (Munich), Dr.
Susanne Schreiber (Berlin)

Vorsitzender des Bernstein Projektkomitees / Chairman of the
Bernstein Project Committee: Prof. Dr. Ad Aertsen
Stellvertretender Vorsitzender des Bernstein Projektkomitees /
Deputy Chairman of the Project Committee: Prof. Dr. Theo Geisel

GEFÖRDERT VOM



Bundesministerium
für Bildung
und Forschung