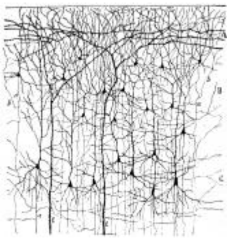
# In silico learning

**Scientists at the Bernstein Centre for Computational Neuroscience, the University of Freiburg and RIKEN Brain Science Institute in Tokyo are investigating learning processes by simulating one cubic millimetre of the brain.**

The brain's learning ability comes from the special properties of neurones, particularly their connections (synapses). All brain activity is mediated by information in the form of short electric impulses that are passed from one 'firing' cell to the next. In so doing, the cells cultivate their capability to propagate signals. If cell A emits a pulse that evokes a response in cell B, this strengthens the contact between the two cells. If there is no such causal relationship, or if cell B fires before cell A, the connection is weakened. As a result of this phenomenon, known as "spike-timing dependent plasticity" (STDP), frequent pairings cause strong neural pathways to develop. Conversely, connections which are infrequently used decline.



The classical picture of a neuronal network such as can be found in the cerebral cortex. The picture was drawn by the Spanish neuroanatomist Ramon y Cajo, who was awarded the Nobel Prize in 1906 for his work. (Photo: Kindly provided by Ad Aertsen)

## Computer simulation reflects properties of the brain

Abigail Morrison, the first author of the published study, was able to show that the basics of learning processes in the nerve cells are more complex than hitherto assumed. (Photo: Morrison)

This "plasticity" of the brain, its ability to adapt physiologically and structurally, is considered to be the foundation of learning. On the basis of a complex computer simulation of 100,000 neurones with 10,000 contacts each – corresponding to about one cubic millimetre of cortex - Abigail Morrison, Ad Aertsen and Markus Diesmann have discovered that STDP may be insufficient to explain the learning processes of nerve cells. The scientists' results will be published in the June issue of Neural Computation.

From earlier studies the researchers knew that their computer simulation reproduced many dynamic properties of the brain.

The virtual neurones fire at about the same frequency as they do in the brain, and the level of activity neither rises nor falls – the system maintains a "dynamic equilibrium". The scientists have extended their model to take into account the plasticity of neuronal connections. To this end, Morrison developed a mathematical formulation of the STDP learning rule that was far better able to describe the experimental results. Thus, the model comes even closer to reality.

## Discovering the secret of neural learning

To investigate whether the computer model can simulate learning processes, the researchers repeatedly stimulated a specific group of neurones. Their initial observations agreed with the learning model predictions: As the stimulated neurones transmitted the stimuli to their downstream neurones, these contacts were strengthened. However, this occurred at the expense of contacts from the upstream neurones in the network. As the stimulated group responded to the external stimulus, the other inputs became redundant and decayed. After a while, the researchers determined that the entire stimulated group had decoupled itself from the rest of the network.

STDP is therefore not sufficient for explaining the process of learning in large neuronal networks as additional requirements must be satisfied in order to enable the system to learn. There are already strong indications as to what these requirements might be. With the simulation of large networks, Morrison and colleagues have a powerful tool for appraising a variety of different models and uncovering the secret of neural learning.

Publication: Morrison, A., Aertsen, A., & Diesmann, M. (2007). Spike-timing dependent plasticity in balanced random networks. Neural Computation, 19 (6) 1437-1467

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**Further information:**

Prof. Dr. Ad Aertsen
Bernstein Centre for Computational Neuroscience
University of Freiburg
Phone: +49 (0)761/203-9549
E-mail: ad.aertsen@biologie.uni-freiburg.de

Dr. Abigail Morrison
Diesmann Research Unit
Computational Neuroscience Group
RIKEN Brain Science Institute
2-1 Hirosawa
Wako City, Saitama 351-0198, Japan
Phone: +81 48 467 9644
E-Mail: Abigail@brain.riken.jp



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