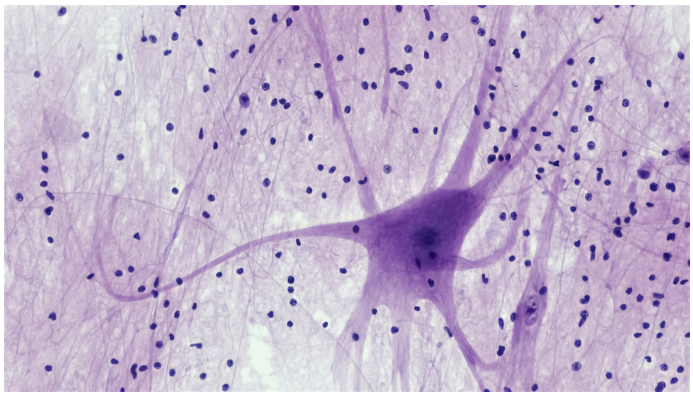
The neurosciences

Robots that move like ants, brain electrodes that alleviate symptoms of Parkinson's, arm prostheses that can be controlled with pure thought power – over the last few years enormous progress has been made in the neurosciences and there has been an increasing shift from pure basic to applied research. There is a great deal of creativity in applied research in Baden-Württemberg. Nevertheless, basic research in the southwest of Germany has never been more diverse. Neuroscientific research has expanded considerably and numerous breakthrough discoveries can be expected. The brain remains the most enigmatic human organ of all and one of the most fascinating mysteries of the 21st century.

Back in 1881, the German anatomist Heinrich Wilhelm Waldeyer coined the term "neuron" to describe the basic structural unit of human ability to think, feel and remember. However, this was only the starting point of many problems that needed and still need to be solved. Nowadays, around 130 years after Waldeyer's observations, researchers understand many aspects of the behaviour of neurons. However, the way the human brain brings about complex human behaviour, emotional states and cognitive abilities still remains one of the biggest mysteries of all time.



Motoneuron of the spinal cord
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Nowadays, researchers prefer to use the term neurosciences rather than neuroscience. Over the last 20 years, the field has become highly diverse and also shares issues with various subdisciplines of biology as well as psychology, physics, chemistry, philosophy and the material and computer sciences. Bert Sakmann, Nobel Laureate, inventor of the so-called patch clamp technique and long-time director of the Max Planck Institute for Medical Research in Heidelberg, is an outstanding example of the historical importance of the state of Baden-Württemberg in the field of neurosciences. The patch clamp technique, in which two electrodes are used to record the change in membrane potentials of individual neurons, has led to the identification of ion channels in cell membranes as well as to more detailed insights into how electrical impulses are conducted in nervous tissue.

From ants to robots

Scientists from Baden-Württemberg are also today among the leaders in neuroscientific research. The cities of Heidelberg and Mannheim, for example, are home to the Interdisciplinary Center for Neuroscience (ICN) which focuses on a broad range of different aspects, in fields including neurophysiology, neurogenetics, neurodevelopmental biology, neurooncology, neurology and neuroinformatics. In addition to the ICN, outstanding neuroscientific research also takes place at many other institutions in Baden-Württemberg. Some of the research activities even have their exotic side: the neurobiologist Prof. Dr. Harald Wolf from Ulm, for example, is investigating the neuronal mechanisms that enable desert ants and other insects to carry out complex movements and navigate in their vast habitat. The results of these studies have also inspired robot development. Researchers led by Prof. Dr. Dr. Hans-Otto Karnath at the Centre of Neurology/ Hertie Institute for Clinical Brain Research at the University Hospital of Tübingen are studying how the perception of human volunteers is impaired by magnetic stimuli. The researchers' goal is to decipher the mechanisms that govern the spatial orientation and perceptual performance of the human brain.

The neurosciences are among the most rapidly developing research fields in the life sciences. On the one hand, the rapid development is due to their huge clinical potential, given that neurological diseases such as Alzheimer's, Parkinson's and multiple sclerosis as well as psychiatric disorders such as depression, schizophrenia and anxiety are still difficult to treat. On the other hand, molecular biology and systems biology - and also high-throughput drug screening methods - have led to the identification of sites in and on neurons that can be targeted with intelligent drugs. In addition, the discovery of neuronal stem

cells and methods for the production of induced pluripotent stem cells (IPPS) from skin tissue, amongst other organs, have led to completely new approaches which regenerative medicine specialists hope will one day enable them to cultivate defective nervous tissue in Petri dishes. And last but not least, basic research into human thinking, feeling and remembering has also been boosted in different ways over the last few years.

Computer brain models

This progress is also related to the most important developments in the neurosciences over the last few years: research into systemic brain aspects has been gaining in importance since the late 1990s, a fact that has been recognised by the German government, amongst others. Since 2004, the German Ministry of Education and Research (BMBF) has been funding the National Bernstein Network for Computational Neuroscience (NNCN), the largest consortium in the world to undertake computer-based neuroscience and also the largest scientific consortium of its kind in Germany. Outstanding research is being carried out at the six Bernstein Centres for Computational Neuroscience that have since been established across Germany in cities including Freiburg, Heidelberg-Mannheim and Tübingen. Learning, memory, perceiving objects, controlling actions and many other things are only possible because different regions and subregions of the brain, in other words billions of neurons, interact with each other. What are the principles that enable neuronal networks to function? Some of the articles in this dossier show that the theoretical branch of the neurosciences, which focuses on the mathematical modelling and computer simulation of neuronal networks, has led to the discovery of some highly interesting principles in the last few years.

Over the last ten years, the discovery of such principles has led to numerous technical achievements: cochlear implants have been used for quite some time to improve hearing; stimulation electrodes are increasingly being implanted into the brains of Parkinson's patients to alleviate limb tremor; and people with paralysed limbs and others suffering from what is known as locked-in syndrome might soon be able to control an arm prosthesis or move a cursor on the computer screen through thought power.

The following example highlights the huge potential of this field: Freiburg neuroscientists from existing networks such as the Brain Machine Interfacing Initiative (BMII) and others have recently joined forces in "Brain Links - Brain Tools", an interdisciplinary research initiative whose goal is to become a cluster of excellence. It has long been clear that the neurosciences have led to the emergence of a new subdiscipline, namely neurotechnology.

The core of human existence

It is important to note that interventions into the brain and thus into the centre of human thinking, feeling and remembering that have become possible are also associated with ethical problems as they directly touch on the core of human existence. Who do we become when our feelings and memories are altered by electrical or chemical stimulation? Neuroethicists and philosophers deal with questions that are of huge importance for the development of our society and our idea of what it is to be human. And such questions also fall into the domain of doctors and researchers.

The present dossier provides insights into specific areas within the broad field of the neurosciences in the form of spotlights and also presents the prominent role Baden-Württemberg scientists play in this field. It focuses on the future visions and problems that current research approaches are bringing about. The Decade of the Brain announced by the American government in 1990 has come to an end, so perhaps this decade, and future ones, can be known as the ‘Epoch of the Brain’.

Dossier

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