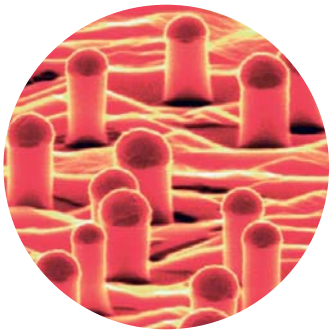
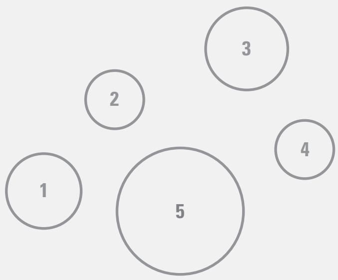
MAX PLANCK SOCIETY

RESEARCH PERSPECTIVES OF THE MAX PLANCK SOCIETY





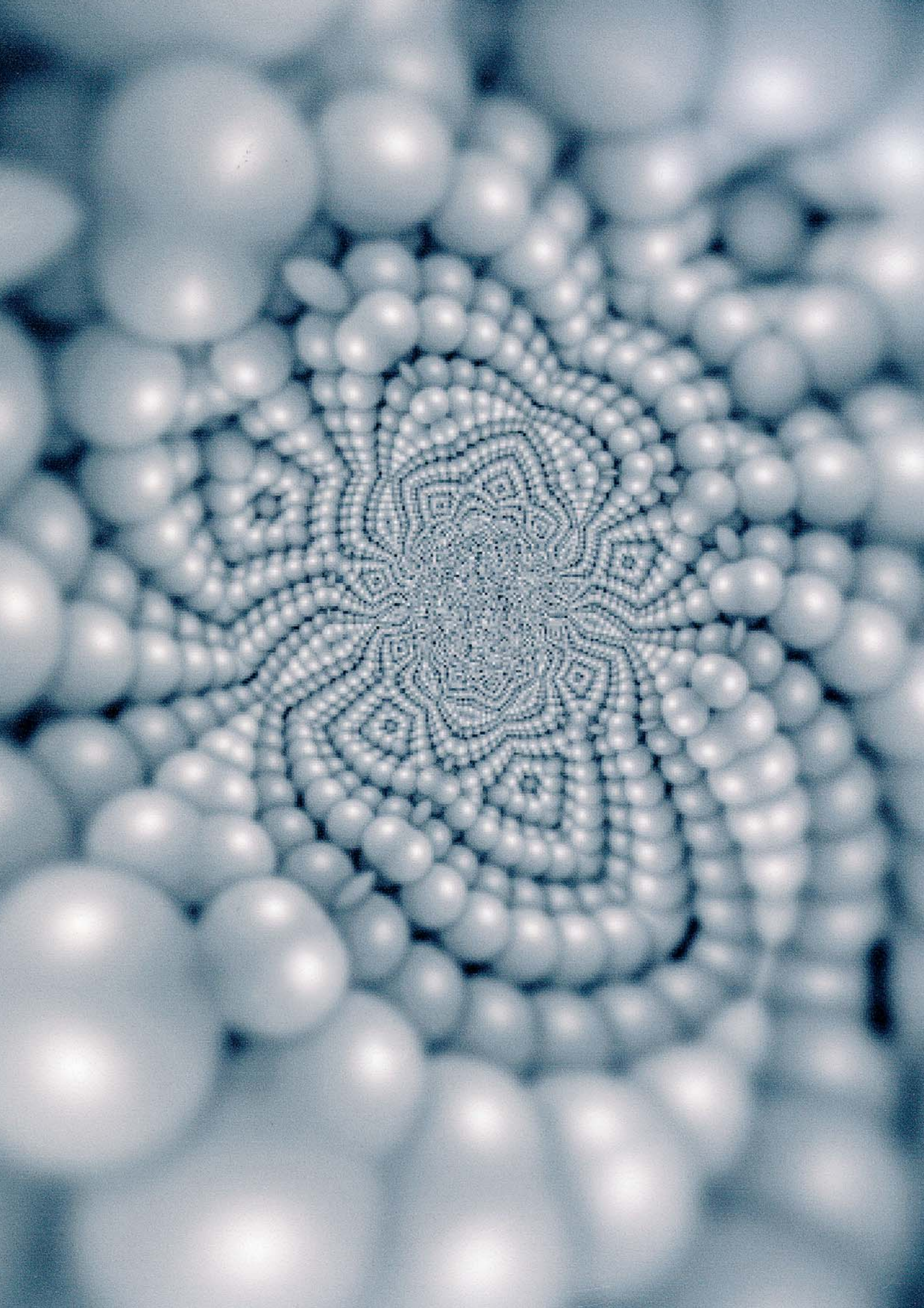
1 Alexander von Humboldt's innovative illustration in his Atlas Géographique des Régions équinoxiales du Nouveau Continent (Paris 1814).

2 The synthetic material polystyrene is used in many areas of life. Special methods facilitate the production of polystyrene particles whose surfaces are modified with polyethylene glycol. This allows biomedical compatibility to be achieved, and the miniballs can be used, for example, as filler material in columns for analyzing biomedical samples.

3 Tiny silicon nanowires protrude from the silicon substrate like matchsticks. Physicists evaporate gold onto a flat silicon disc at 525 degrees Celsius and then expose it to a stream of silicon vapor. The nanowires begin to shoot up wherever there are gold droplets on the surface.

4 When high-energy light meets matter, an interaction occurs at the material interface, producing electrons that fly off the material in all directions. Physicists capture the negatively charged electrons with the aid of this glittering golden sphere, and study their speed and direction.

5 The Neisseria gonorrhoeae bacteria, dyed red in this microscopic image, are only about one micrometer in size. In an infection, they adsorb to human epithelial cells, shown here in green, which attempt to repel the attackers (red) on their surface.



NOTE FROM THE PRESIDENT

Poets and scientists have always been deeply attracted by the idea to look into the future. We are always curious to know the next step, be it with regard to TV series, comic strips, scientific and technical developments, or our own lives. Science is a consistently forward-moving part of our culture, always focused on something new. And the novelty is not only what has never existed before, but also what has never been thought before. A context newly recognized by a scientist, an observation made for the first time – all this is built on the human quest for discovery which appears to be integral to our nature. History suggests, as evidenced by such finds as the famous sun disc of Nebra in Saxony-Anhalt, that our ancestors in prehistoric times were already trying to investigate the laws of nature. Our quest for discovery is reinforced by the challenges we encounter in our daily lives and our attempts to improve the human condition. The results range from the invention of paper to that of the internet, from the first bronze casts up to modern composite materials, from the first medicine brewed by Medieval monks all the way to newly developed drugs against cancer and AIDS.

The President of the Max Planck Society, Peter Gruss

While in past times discoveries and inventions were a rather accidental and isolated phenomenon, scientific research today is supported by government and industry in a target-oriented manner. In this respect, basic research has a special role to play. Because without fundamental insights into the principles of animate and inanimate nature, application-oriented research lacks all foundation. Neither laser nor GPS would have been invented had Albert Einstein not reformulated our understanding of the laws of energy, matter, light, and gravitation 100 years ago. Incidentally, the great theorist Einstein himself filed fourteen patents, and was directly involved in numerous other inventions.

In Germany, the two major pillars of basic research are the universities and non-university research organisations such as the Max Planck Society. Together with other institutes that are dedicated to application-oriented or strategically programmatic oriented research, this research system has proven itself to be most valuable in times of persistent and increasing international competition. To achieve outstanding results, science needs scope for autonomous development in appointing the best scientists as well as in selecting research topics which seem particularly challenging and innovative from a scientific point of view. In choosing its goals, the Max Planck Society keeps redefining the direction it has taken. The first chapter of this brochure contains a brief survey of the society's organization and its procedures in the planning of its perspectives.

What subjects are at the top of our agenda in the next few years? If you are interested in more details, you will find the following chapters illuminating: the research spectrum at the Max Planck Institutes ranges from the development of the cosmos to biological variety and all the way up to the integration of different cultures. In investigating such a wide array of subjects, the Max Planck Society is laying the foundation for meeting the challenges of society. Just a few examples: much discussed demographic changes lead to fundamental questions concerning the causes of aging. What are the genetic prerequisites of aging? How can diseases occurring in old age be recognized earlier and treated more effectively? How can human physical and mental abilities be maintained in old age? What social changes are required in order to use the productivity of older people more effectively? Answers to these questions will be paramount in tackling the changes in the age pyramid.

Within the next few years, legal and social sciences will increasingly ponder the issues of how to counter international terrorism. With the focus and reach of various terror organizations no longer restricted to individual countries, such organizations are considered no longer a local but also a global threat. Contemporary terrorism is organized differently than terrorism in the 20th century; it has different sources of funding and employs new strategies of violence and blackmail. The Institutes of the Max Planck Society provide an interdisciplinary platform for an in-depth analysis of the security challenges raised by modern terrorism.

The question of how we are to meet future energy supply demand without causing further global warming is also of global interest. In many Institutes of the Max Planck Society, scientific researchers are involved in fundamental research on the components for an energy circulation system based on hydrogen – starting from improved catalytic methods of producing hydrogen to research on how to imitate photosynthesis and all the way up to new methods storing hydrogen.

Max Planck Institutes are no ivory towers. Basic research and application-oriented research are only distinguished in terms of time: in general, basic discoveries can be utilized only later in time. The products resulting from basic research are genuinely innovative. Another promising field, albeit presently still far removed from application, is quantum physics. Scientists try to purposely influence the movement and states of microscopic matter in a controlled manner. To this end, precisely controlled light is used as a unique instrument. Such experiments show completely new possibilities for the processing of information, on the basis of which it might be possible to develop a new type of computer, a quantum computer. Quantum computers could offer an opportunity to understand complex transactions which cannot be simulated with classic computers.

Additional resources and capacities as well as special know-how are required, however, in order to make the results of basic research ready to be brought to the market. The market for venture capital in Germany, however, is very limited. We have therefore thought about potential improvements for technology transfer in Germany. Our idea is to start up an innovation fund for German research. Such a fund should not only have the objective of financing further development of scientific results for application, but also of supporting such a development in terms of contents. Whether political decision-makers take up this idea is not yet certain. Such a model would offer additional opportunities for the German economy.

All our efforts can only lead to success if expenditure on research and education is seen as an investment into the future. Excellent science requires reliable framework conditions. German research is not positioned badly, as evidenced by the number of most frequently cited publications: Germany ranks third, right behind the USA and Great Britain. With the support of politics and industry we can expand on this excellent position. One small contribution to this would be not to focus so much on the problems that the future might bring but rather on the opportunities it might offer – in particular on the research perspectives which might contribute to mastering the challenges of the future.

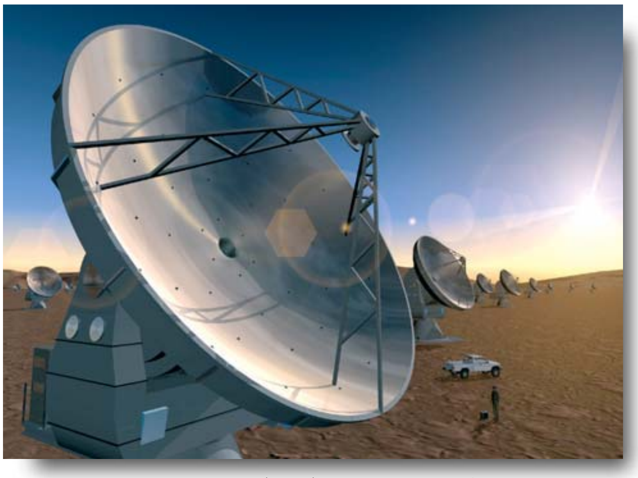
Peter Gruss
President of the Max Planck Society

BEGINNING WITH THE BIG BANG

According to our current scientific understanding, all life on Earth can be traced back to the Big Bang. Although mankind's preoccupation with space and the stars grows out of an interest in scientific discovery, we are simultaneously confronted with the question of human origin and development. It is for this and other reasons that astronomy is one of the oldest natural sciences. Astronomy and astrophysics are currently experiencing a boom. The notion of space has changed, almost completely unnoticed by the public: it is not quite as empty as assumed, but rather full of dark matter and dark energy. The expansion of the universe is still accelerating, and enormous black holes determine what happens at the centers of galaxies. These observations also have implications for the physics of elementary particles. The cross-fertilization of the two fields is generating a new quality in science. This is also true for research into plasmas, where atomic nuclei and electrons coexist in a disassociated state. Plasmas are found in the sun, where nuclear fusion produces energy, enabling life on Earth, warmth and light, but also affecting our climate. However, plasmas also play a major role in many areas of day-to-day life. In the vision of unlimited energy production through fusion power plants, high-energy plasmas must even be captured and controlled. These research areas are typical topics of the Max Planck Society. They serve to increase our insight, but also provide a more exact picture of the universe and promote many new technological applications, which are then often used for other purposes, as well.

THE DEVELOPMENT OF THE COSMOS

Astrophysics is currently experiencing some major breakthroughs, for example, in the measurement of dark matter and dark energy, as well as in the discovery of black holes and extrasolar planets. Important research subjects for the future deal with the origin and development of the universe as a whole, with galaxies and supermassive black holes, and with stars and planetary systems. Here, new observation possibilities go hand in hand with answers to fundamental astrophysics questions. The galaxies in the early universe are being observed in the long-wave range of the electromagnetic spectrum with the airborne SOFIA telescope, ESA's Herschel infrared satellite and the James Webb Space Telescope (JWST). From the ground, adaptive optics and interferometry allow ultra-high resolution images with the Very Large Telescope Interferometer and the Large Binocular Telescope (LBT). Beginning in 2010, the global collaboration that developed the Atacama Large Millimeter Array (ALMA) with its 64 antennas atop the Chilean Chajnantor plateau will come to fruition, and it will be possible to spatially resolve dust and gas masses of even the most distant galaxies and protoplanetary disks, and to analyze their structure and dynamics. ESA's Darwin mission will make it possible to find planets that are similar to Earth, and to search for signs of biological activity. The hot and high-energy universe will be examined by ESA's future XEUS mission and in newly-opened observation windows resulting from the IceCube neutrino telescope being built in the Antarctic, the Cherencov telescopes H.E.S.S. and MAGIC, and the LISA Laser Interferometer Space Antenna for detecting gravitational waves.



MPI for Radio Astronomy, Karl M. Menten

The Atacama Large Millimeter Array (ALMA) with its 64 antennas for the millimeter and submillimeter range – developed and financed through a global cooperation project – is taking shape atop the Chilean Chajnantor plateau.

PARTICLE AND ASTROPARTICLE PHYSICS

In the last decade, the dovetail connection between the physics of elementary particles and astrophysics became ever tighter and more intense. The analysis of elementary particles from the cosmos provides information about new properties of these particles and, at the same time, opens a new window to the cosmos. A central issue of modern astrophysics and particle physics is the search for the mysterious particles that make up dark matter, thus constituting the majority of the mass in the universe. This issue is addressed from various angles. At CERN's LHC storage ring, the particles of dark matter can potentially be generated in high-

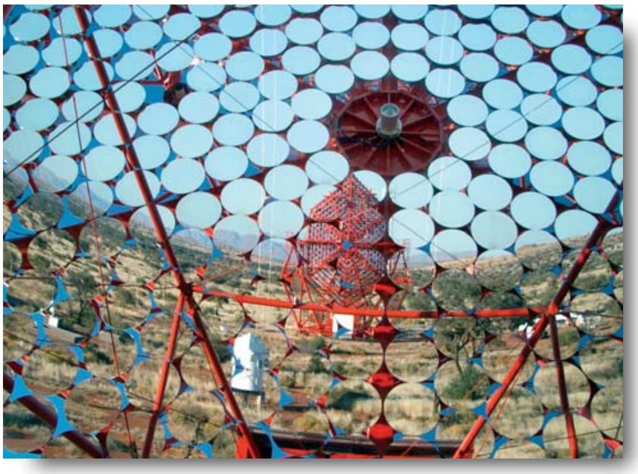
PARTICIPATING INSTITUTES

- MPI for Astronomy, Heidelberg
- MPI for Astrophysics, Garching
- MPI for Chemistry, Mainz
- MPI for Extraterrestrial Physics, Garching
- MPI for Gravitational Physics, Golm/Hanover
- MPI for Mathematics, Bonn
- MPI for Nuclear Physics, Heidelberg
- MPI of Physics, Munich
- MPI of Plasma Physics, Garching and Greifswald
- MPI for Radio Astronomy, Bonn
- MPI for Solar System Research, Katlenburg-Lindau

energy collisions. To analyze the collision products, complex particle detectors are needed, such at the ATLAS detector with its many millions of detector elements. Using highly sensitive detectors in underground labs, as in the case of the CRESST experiment, researchers aim to make visible the minor recoils transmitted when particles of dark matter in the Milky Way's halo collide with atomic nuclei. The H.E.S.S. and MAGIC telescopes measure high-energy gamma photons from the cosmos in order to identify and map cosmic particle accelerators. This example also demonstrates how closely particle physics and astrophysics have merged in the search for particles of dark matter, and how experimental technologies are transferred from one field to the other.

PLASMA RESEARCH – UNDERSTANDING WHAT MAKES UP THE UNIVERSE

Plasma research in the Max Planck Society addresses a wide spectrum of issues, ranging from dynamic processes in astrophysical objects to turbulent currents in magnetically enclosed nuclear fusion plasmas on Earth. Here, researchers use commonalities from experimental diagnostic methods and theoretical descriptions. This close interaction between theory and experiment has allowed us to make enormous advances in understanding. Future research projects planned around the world, such as the Solar Orbiter satellite and the nuclear fusion experiment ITER – in conjunction with the still rapidly increasing opportunities for numerical computer simulation – will lead to a new quality of understanding of plasmas. Because this field of research is so broad, it affects such diverse areas as forecasting space weather, understanding star explosions and controlling nuclear fusion.



H.E.S.S. collaboration

The reflector of one of the H.E.S.S. telescope mirrors the Namibian countryside and another telescope. The H.E.S.S. system comprises four large telescopes for detecting high-energy gamma radiation from the cosmos.

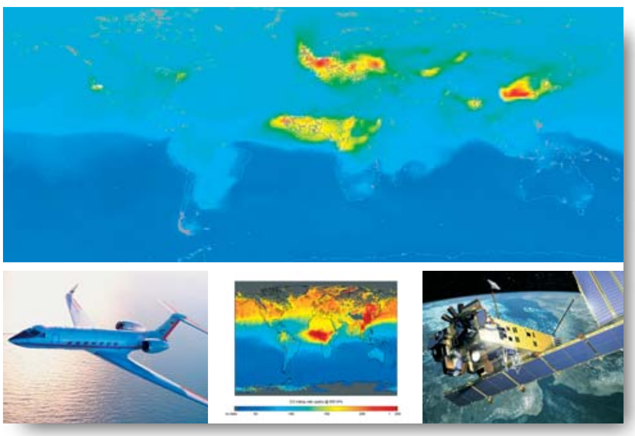
SPACESHIP EARTH

To ensure that life on Earth will be worth living for generations to come, we must use our resources responsibly and in harmony with nature. The UN has even recognized the right to sustainable development as a fundamental human right, and as a strong motivation for basic research. Scientists want to understand how human influence interferes in and alters the Earth's habitat. To do this, they must geo-scientifically analyze the major material flows, as well as their interconnections and "sensitivities." Since a restrictive approach to environmental protection is not socially viable, developments, such as the shrinking supply of fossil fuels, are posing specific challenges for chemistry, physics and the engineering sciences. Basic research must identify alternatives to traditional energy generation or environmental toxins. Biology offers solutions, too: the major material flows, such as air, water and pollutants, are largely controlled by microorganisms, about which little is yet known. The study of microorganisms is necessary in order to develop reliable Earth models. In addition, new bacteria and new enzymes are facilitating new processes and cycles. The institutes of the Max Planck Society are taking an open, forward-looking and interdisciplinary approach to the topic of sustainability, and are attempting to provide society with the necessary tools. The Max Planck Society believes its role to be to support political decisions with more accurate damage models, and to identify technological alternatives.

THE EARTH SYSTEM

Global change impacts all components of the Earth system: oceans, the atmosphere, solid ground, the biosphere and humans. In order to meet the scientific and social challenges of global change, these components must be studied as interacting parts of an integral system, and we must learn to understand their interdependencies and mutual feedback. Max Planck Institutes, together with additional partner institutes, are planning an integrated approach to researching the Earth system. They will focus on the interdependencies between human activities, land ecosystems, oceans and the atmosphere using airborne measurement methods, remote sensing and modeling. Due to their global importance, these tasks are closely dovetailed with major research projects at the international level, and in particular with the International Geosphere-Biosphere Program. The long-term goal of this research is to develop an understanding of the Earth system, which will help people comprehend the changes taking place in the world and act in harmony with this information. Only in this way can we determine and scientifically establish which political and economic measures are urgently needed to protect the Earth system, and how we can use our planet's natural resources in an optimal and sustainable manner.

DLR/ESA/NASA



An integrated approach to researching the Earth system requires measuring campaigns, remote sensing and numerical modeling. These components are represented here by the HALO research aircraft (left), the Envisat satellite (right), the global distribution of carbon monoxide as measured from space (center) and the distribution of this same trace gas as predicted using a numerical model.

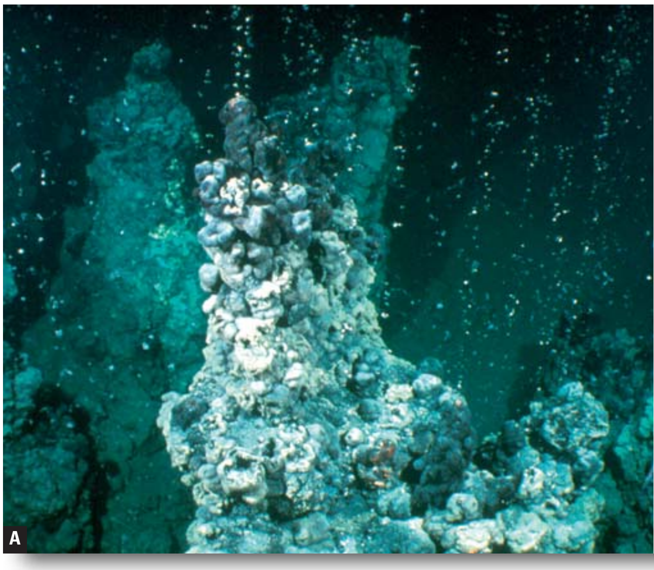
THE MICROBIOLOGY OF ENVIRONMENTAL PROCESSES

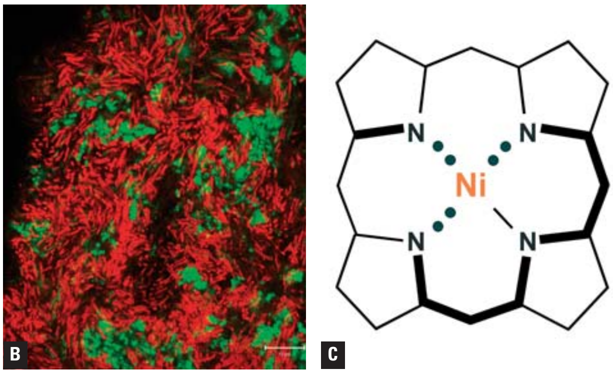
Environmental microbiology refers to research at the interfaces between biology, chemistry and geology. It deepens our understanding of how microorganisms, in interaction with plants, animals and humans, shape and maintain the Earth's biosphere, and how they are influenced by changes in the environment. Both microorganisms and bacteria are omnipresent in ground and water. They fulfill essential functions in material cycles, although they and their functions are very different and only partially understood. As yet unknown species, often with novel enzymes for novel reactions, are being continually discovered. What has always been interesting is their use in biotechnology, for example to synthetically manufacture hard-to-access substances, or to degrade specific toxic compounds. The spectrum of methods used in environmental microbiology ranges from modeling global material cycles to analyzing genomes. On the one hand, the field aims to study which bacterial processes take place in wetlands, oceanic upwelling areas or in the deep sea, and to what extent these processes are influenced by environmental changes (including anthropogenous ones).

PARTICIPATING INSTITUTES

- Fritz Haber Institute of the MPS, Berlin
- MPI for Biogeochemistry, Jena
- MPI for Bioinorganic Chemistry, Mülheim an der Ruhr
- MPI for Chemistry, Mainz
- MPI of Coal Research, Mülheim an der Ruhr
- MPI of Colloids and Interfaces, Potsdam
- MPI for Meteorology, Hamburg
- MPI for Marine Microbiology, Bremen
- MPI for Terrestrial Microbiology, Marburg
- MPI for Nuclear Physics, Heidelberg
- MPI of Plasma Physics, Garching and Greifswald
- MPI for Polymer Research, Mainz
- MPI for Solar System Research, Katlenburg-Lindau
- MPI for Solid State Research, Stuttgart

GHOSTDABS project, University of Hamburg (A,B); MPI for Marine Microbiology (C)





Environmental research from great to small.
A) At a depth of 200 m in the Black Sea, where there is no oxygen, microorganisms oxidize discharged methane. Here, limestone collects in the form of bulbous towers that characterize a primitive underwater landscape absent of any higher life forms. B) A pile of cells from the towers, comprising Archaea and bacteria (dyed red and green, respectively). C) The basic chemical structure of the decisive nickel factor that makes the biochemical attack on the methane possible (bold: delocalized electrons).

On the other hand, it analyzes precisely which species of bacteria are responsible for which process, and which molecular mechanisms take place in cells. Here, molecular biological technologies, especially specific RNA and gene detection, have proven to be very successful for identifying microorganisms directly from the ground and water.

PRINCIPLES OF A SUSTAINABLE ENERGY SUPPLY – DECENTRALIZED SOLUTIONS BASED ON THE EXAMPLE OF HYDROGEN

Long-term supply of energy is one of the great challenges for the coming decades. In this regard, the Max Planck Society is researching the principles of nuclear fusion, as well as fundamental questions relating to hydrogen as a flexible energy carrier. For the latter to provide a sustainable energy supply, the hydrogen must be produced from renewable resources. Many institutes of the Max Planck Society are working on fundamental components for a hydrogen-based energy cycle – from improved catalytic methods for producing hydrogen to imitating photosynthesis and storing hydrogen in innovative storage media. This work is not aimed at developing technologically utilizable prototypes, but at forming the scientific foundation for these system concepts. Basic research in the fields outlined here is expected to establish the scientific prerequisites for creating a solid and sustainable basis for our energy supply for years and decades to come.

EVOLUTION AND BIOLOGICAL DIVERSITY

Life on Earth originated nearly four billion years ago. Since then, due to the complex mechanisms of evolution, it has developed in explosion-like thrusts into infinite variety. This is true for genes, for organisms and for ecosystems. Of these, genetic diversity can be most clearly described: it is determined by comparing genome sequences. Organismic diversity is more difficult to define, since organisms of one species, although always closely related, are usually not genetically identical. And even when they are, they may exhibit differing features under differing environmental conditions. In addition, organisms may lose genes, assimilate foreign genes and undergo genome reorganization without becoming a different species. With regard to the diversity of ecosystems, the interactions of various organisms with one another and with inanimate nature must be taken into consideration as well. Biodiversity reflects the different conditions for ecological selection in space and time. Genetic adaptation optimizes biological features for the ecological conditions in which they exist. Evolutionary theory models allow for predictions about the changes in biological features under changing ecological conditions.

BIODIVERSITY RESEARCH

Research on global biodiversity and the ensuing activities undertaken to maintain it are among the most important and urgent tasks for the future of science and its practical application. To date, biodiversity research has largely been limited to taking stock of species diversity among higher organisms – that is, plants and animals. However, this does not account for genetic diversity within species, the diversity of environmentally induced external appearances and the complex interactions within a biotope, or for the conditions and mechanisms for the creation and continuing evolution of biodiversity. Fundamental new findings on this have become possible thanks to rapid advances in comparative genome research and bioinformatics. This, together with an inter-institutional network and the establishment of additional projects, will form the basis for further expanding biodiversity research.

MPI for Biogeochemistry/Jussi Baade

Biodiversity experiment fields planted with grasses and herbs in the Saaleaue near Jena.

MPI for Plant Breeding Research

Eggplant comes in many sizes, shapes and varieties.

PLASTICITY AND TRAIT DIVERSITY IN PLANTS

Plants are the main source of food for humans, produce valuable raw materials and are an indispensable part of Earth's ecosystem. We now have a complete catalog of genes for one wild and one cultivated plant (Arabidopsis and rice). One key challenge is to decipher the inner logic of the ordered interplay of gene products in and between cells in forming complex traits (such as plant architecture, disease resistance and yield). To do this, scientists want to understand how the coaction of numerous molecules results in regulatory networks with the characteristics of a system. It is expected that unravelleling these regulatory principles will help understand how natural trait diversity, a characteristic of ecosystems, originates. Genetically determined trait diversity is the raw material of plant breeding. Understanding the laws of plastic trait expression will initi-

PARTICIPATING INSTITUTES

- MPI for Biogeochemistry, Jena
- MPI for Biological Cybernetics, Tübingen
- MPI for Brain Research, Frankfurt
- MPI for Chemical Ecology, Jena
- MPI for Computer Science, Saarbrücken
- MPI for Developmental Biology, Tübingen
- MPI for Evolutionary Anthropology, Leipzig
- MPI for Human Cognitive and Brain Sciences, Leipzig and Munich
- MPI of Immunobiology, Freiburg
- MPI of Limnology, Plön
- MPI for Marine Microbiology, Bremen
- MPI of Molecular Cell Biology and Genetics, Dresden
- MPI for Molecular Genetics, Berlin
- MPI of Molecular Plant Physiology, Potsdam
- MPI for Ornithology, Seewiesen
- MPI for Plant Breeding Research, Cologne
- MPI for Psycholinguistics, Nijmegen
- MPI for Terrestrial Microbiology, Marburg

ate a radical change in plant breeding in the next decade. This change will make it possible for the first time for humans to influence even complex traits in a targeted manner and in line with their needs.

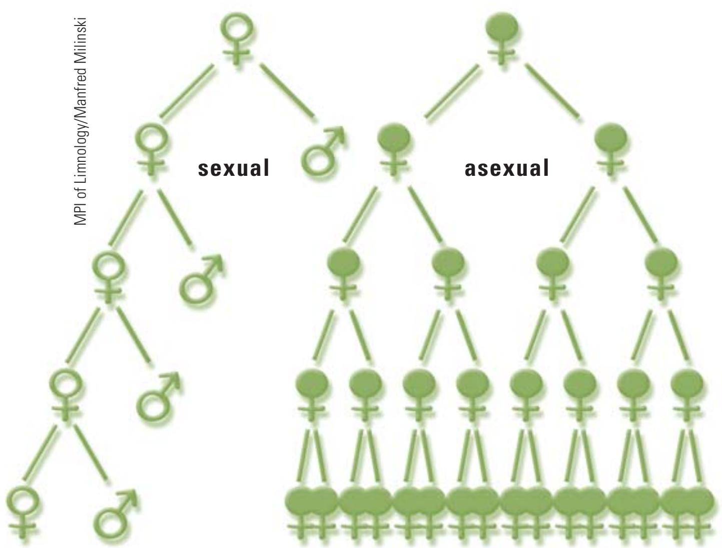
EVOLUTION

As a result of the mechanism of evolution identified by Charles Darwin, all living beings have traits that are optimized for specific tasks. If the ecological conditions for selection are known, the expected optimum can be calculated and, based thereon, experimentally verifiable predictions can be made, for example about physiological mechanisms. This makes research into such mechanisms more efficient. Conversely, for every biological trait, it is possible to calculate the ecological conditions under which it constitutes the optimum. This makes it possible to predict whether an observed trait will remain stable or whether, for example, it will undergo climate-induced evolutionary change. To remain stable, many widespread traits, such as sexual reproduction, require boundary conditions that would not have been recognized without evolutionary theory modeling.

THE ORIGINS OF MODERN MAN

Man influences life on Earth more than any other species, and it is the only species that actively reflects on its own history and future. The sequencing of the human genome and the genomes of other species opens up new opportunities for comprehending the biological reasons for mankind's unique characteristics. This requires a comprehensive interdisciplinary approach that explains in empirical terms the historical, cognitive and cultural prerequisites for anthropogenesis. As an interdisciplinary research organization, the Max Planck Society is ideally positioned to assume a leading role in this work. In the coming years, interdisciplinary and comparative research projects will investigate the biological and cultural prerequisites for the unique role of modern man on our planet.

MPI of Limnology/Manfred Milinski



As sons do not materially contribute to the next generation, sexual reproduction is hopelessly inferior to asexual reproduction in terms of efficiency. Nevertheless, almost all animals and plants reproduce sexually.

ADVANCED MATERIALS SHAPE THE FUTURE

Sophisticated material structures made to measure are the building blocks of all current and future technologies ranging from information and communication, medicine and food, energy and environment, all the way to transport and space exploration. In order to tackle the technological challenges on the horizon, however, we have to make strong and sustainable efforts in fundamental research today. nNanoscientists have already embarked on this quest: on the one hand they create smart artificial nanostructures with atom-control, which do not exist in nature, on the other, they exploit biomimetic processes borrowed from nature in order to construct lightweight architectures with unprecedented properties. In this endeavour, physicists, chemists, materials scientists and biologists work together in an interdisciplinary manner; a key research strategy of the Max Planck Society. New super-hard materials, supra-lubricant surfaces, novel materials for hydrogen technology, single-electron transistors, organic electronics and quantum computers are only a few examples of the many ideas developed in high tech materials science laboratories. Max Planck research labs will focus their efforts and expertise to discover new materials and materials phenomena, and to tailor material functions to optimum performance in order to assure that the toolkit of materials is filled for tomorrow's technologies.

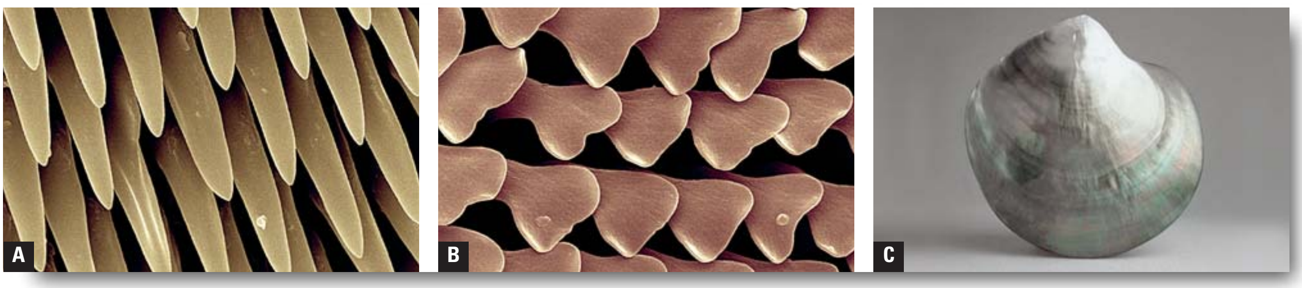
BIOMIMETIC MATERIALS RESEARCH AND BIONICS

Natural raw materials, such as silk, wood, bamboo and enamel, are still superior to many technological materials, even in the 21st century. This is because nature, which is continually optimized through evolution, makes optimal use of the strengths of each individual molecule in its place in a nano- and microstructure. At the same time, nature is limited to just a few basic materials. It does not know any metals or semiconductors, for example. The goal of biomimetic materials research at the Max Planck Society is to use careful analysis to understand the principles of nature and apply them to synthetically produced materials – not to copy, but to augment them. The great potential of biomimetic materials research lies in the combination of miniaturization and multifunctionality, which we can expect to yield many potential applications in optics, microelectronics and sensorics, as well as to greatly improved structural materials for aircraft, high-rise and bridge construction. Biomimetic materials research also requires a fundamentally interdisciplinary approach with contributions from chemistry, physics, biology and the engineering sciences. It is also necessary to develop and use combined characterization methods that account for the biological character and the nanostructure of these samples.

MODERN FUNCTIONAL MATERIALS

Materials with specific functions and their development have shaped the history of mankind. The industrial revolution of the 19th century would have been inconceivable without the development of steel as a construction material, and the computer revolution in the past fifty years is inextricably linked to silicon technology. While in the past, materials with specific functions were often discovered by accident, the design and synthesis of functional materials is radically changing at the dawn of the 21st century. Designs are now starting from the atomic and molecular level, taking the elementary building blocks' electronic structure into full account. A specific design can be translated into a functional material with well defined and predetermined properties by combining fundamental microscopic knowledge with precise synthesis and fabrication techniques.

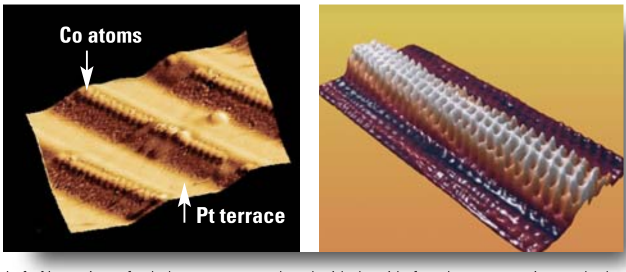
(A+ B) MPI for Metals Research/Stanislav N. Gorb; (C) MPI of Colloids and Interfaces



A feat of nature: mother-of-pearl (fig. C) prevents any accumulations – unlike other surfaces, such as the interlocking structure of the dragonfly head (figs. A and B), which is constructed as a link.

PARTICIPATING INSTITUTES

- Fritz Haber Institute of the MPS, Berlin
- Max Planck "Mechanics of Polymers" research group at the Darmstadt University of Technology
- Max Planck "Optics, Information and Photonics" research group at the University of Erlangen-Nuremberg
- MPI of Biochemistry, Martinsried
- MPI for Biophysical Chemistry, Göttingen
- MPI for Chemical Physics of Solids, Dresden
- MPI of Coal Research, Mülheim an der Ruhr
- MPI of Colloids and Interfaces, Potsdam
- MPI for Dynamics and Self-Organization, Göttingen
- MPI for Gravitational Physics, Potsdam, Hanover
- MPI for Iron Research, Düsseldorf
- MPI for Medical Research, Heidelberg
- MPI for Metals Research, Stuttgart
- MPI for Nuclear Physics, Heidelberg
- MPI for the Physics of Complex Systems, Dresden
- MPI of Microstructure Physics, Halle
- MPI of Neurobiology, Martinsried
- MPI of Plasma Physics, Garching and Greifswald
- MPI of Quantum Optics, Garching
- MPI for Solid State Research, Stuttgart



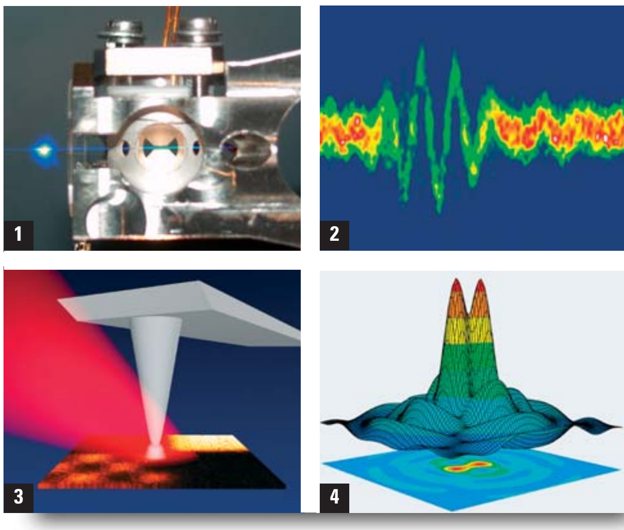
MPI for Solid State Research

Left: Nanowires of cobalt atoms are produced with the aid of modern preparation methods. Right: Carbon nanotubes are suitable for building classical and quantum mechanical components.

The successful implementation of this bottom-up strategy requires a detailed understanding of the individual building blocks and their interactions over microscopic and mesoscopic distances. Specifically, there is a crucial need for the continuing development of sophisticated synthesis techniques and analytic tools with atomic precision. The success of this endeavor will find wide application in many fields, ranging from lightweight, high strength mechanical components to energy-related technologies and to quantum coherent materials that may result in novel schemes of computation and communication.

PHOTONICS AND QUANTUM OPTICS

Exerting selective influence on the states and movement of microscopic matter is one of the great tasks of modern science. Precisely controlled light is a unique instrument for executing this task. Scientists at the Max Planck Society, frequently also in national and international collaborative efforts, are developing ultramodern coherent light sources and the latest optical technologies to provide deep insight into microscopic structures and processes of matter. They also make it possible to precisely measure the properties of matter and control their movement. The expected implications range from the application of quantum effects (quantum information technology and quantum gases), precise testing of theories of the very small (microcosm) and the very large (universe), to real-time tracking of processes deep inside atoms, molecules and biological matter with attosecond resolution.



MPI of Quantum Optics (1) MPI of Quantum Optics, TU Vienna/Ferenc Krausz (2) MPI for Biochemistry/Nenad Ocelic (3) Max-Planck Research Group for Optics, Information and Photonics/Susanne Quabis (4)

1) An optical resonator creates the quantum interface between a stationary atom and a moving photon. A cloud of atoms (left) is transferred between two highly reflective mirrors (center) with a laser beam.
2) The photo of an attosecond X-ray flash shows that for the first time, light oscillation is perfectly controlled and can be measured and therefore can be used for precise control of electrons in atoms and molecules.
3) Illuminating the tip of an aerial with laser light creates a tiny focal point which allows an object to be scanned with nanometer resolution and viewed with ultrasharp clarity under a microscope.
4) Focusing light in an area smaller than the wave length, overcoming traditional limitations of optics.

INFORMATION: TECHNOLOGY, LIFE AND CULTURE

Knowledge is not self-generating. It is created by a continual linkage of information, analysis and insight. Knowledge requires information, and knowledge creates information. The dynamics of modern scientific development are based on the speed and directness with which new information is shared. Informatics has fundamentally changed the way we live and work. We are in the midst of a knowledge transfer revolution unlike any that has been seen since the invention of printing more than 500 years ago. The use and creative development of this new technology unites the various sections of the Max Planck Society. How can information be processed with machines? How can the interface between man and machine be raised to a level that is suitable for mankind? These are two key questions that are being addressed in the Chemistry, Physics & Technology Section (CPTS). A research unit in the Biology & Medicine Section (BMS) focuses on how living beings process information and, in doing so, how mind and body interact. Scientists in the Humanities Section want to understand what significance knowledge and information have for society today and what significance they had previously; how new technological possibilities can be used to gain scientific insights, and what consequences we can expect the use of computer science to have for modern science and society.

FOUNDATIONS OF NEW INFORMATION TECHNOLOGIES

Computer science or informatics is one of the central innovative forces of the 21st century. It is changing how we live, learn, work and play by revolutionizing business methods and communication. To maintain Germany's innovative power and competitive strength, basic research must also be further intensified in computer science. From a scientific standpoint, computer science has long since transformed itself from a purely auxiliary science – that is, computing power used as a tool in other traditional research domains – into an independent research field. In view of the greatly increased importance of computer science and the novel questions arising in basic research, the Max Planck Society has further expanded its research in this field and established an Institute for Software Systems. The new Max Planck Institute is dedicated to investigating the scientific foundations for developing complex software systems. Their smooth functioning is crucial to company-wide business processes, for example, as well as global telecommunications networks and large segments of automotive and aircraft manufacturing. Within the Max Planck Society research in the field of "intelligent computer systems" has been identified as another highly innovative focus with great potential. As this field involves manifold ties to the humanities and life sciences, in particular to the neurosciences, inter-sectional research is planned.

INFORMATION TECHNOLOGY IN THE HUMANITIES

Thanks to electronic computing, networking and presentation, researchers in the humanities, too, can discover, analyze and archive repeating patterns and particularities in large data quantities to an extent not previously known. Their research objects are no longer tied to a given location – they can be portrayed and linked throughout the

This sequence of images depicts a reconstruction of a bronze bust of Max Planck. The individual pictures in the sequence show: the original bust (left), a reconstruction of the 3-D geometry using an unstructured point cloud (fig. 2), a polygon mesh produced by triangulation of the point cloud (fig. 3), a shaded polygon mesh (fig. 4) and the final reconstruction (including reconstruction of the material parameters) (right). The image on the right is thus a full digital copy of the original bust.

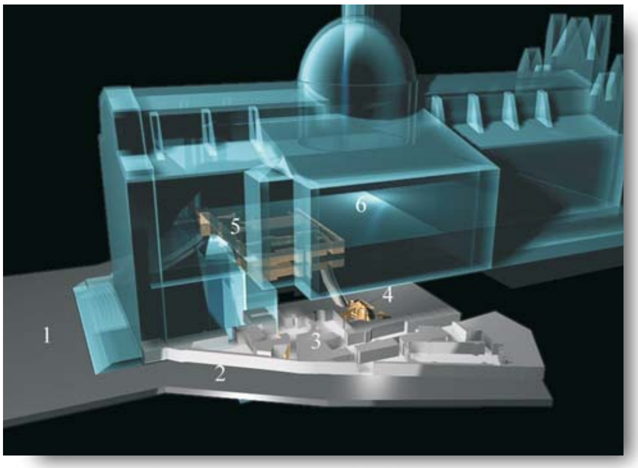
MPI for Computer Science/Hendrik Lensch et al.

PARTICIPATING INSTITUTES

- Art History Institute – MPI, Florence
- Bibliotheca Hertziana – MPI for Art History, Rome
- MPI for Biological Cybernetics, Tübingen
- MPI for Brain Research, Frankfurt/Main
- MPI for Evolutionary Anthropology, Leipzig
- MPI of History, Göttingen
- MPI for the History of Science, Berlin
- MPI for Human Cognitive and Brain Sciences, Leipzig and Munich
- MPI for Human Development, Berlin
- MPI for Informatics, Saarbrücken
- MPI for Intellectual Property, Competition and Tax Law, Munich
- MPI for Psycholinguistics, Nijmegen
- MPI for Research on Collective Goods, Bonn
- MPI for Software Systems, Kaiserslautern and Saarbrücken
- MPI for the Study of Societies, Cologne

and all other institutes of the Humanities Section

Simone Santacaterina, Studio di Architettura Tarcisio Bratto



A digital reconstruction of the Siena Cathedral, making visible the subterranean rooms (4 and 5), parts of which were recently rediscovered. (1) Piazza San Giovanni, (2) Via dei Fusari, (3) the former San Giovannino Oratory, (6) the level of the cathedral floor.

world. Material that once belonged together and is now spread throughout the world can be brought together virtually and represented visually. The increased use of information technology in the historical sciences and other areas of the humanities is accordingly leading to fundamental changes in working modes, and to completely new research methods. In the field of linguistics and related disciplines, for example, digitized language corpora supplemented by metadata and made accessible through intelligent search methods have made it possible, for the first time, to fundamentally describe many languages that are barely documented and threatened with extinction. In addition, powerful computers make it possible to examine the often inadequately known properties of statistical methods. Computers linked through the World Wide Web allow location-independent psychological and sociological analyses to be carried out, with central data storage and continuous adaptation of the tasks to be processed. The Max Planck Society will be promoting computer-assisted research in the humanities through inter-institute and inter-sectional cooperation.

SCIENCE DYNAMICS AND SOCIETAL DYNAMICS

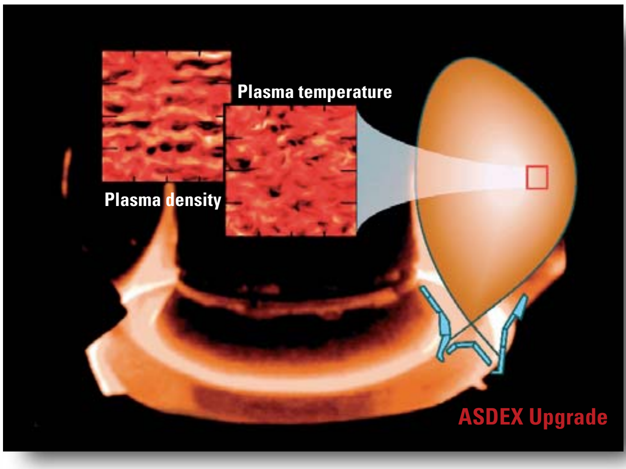
The relationship between science and society is fraught with tension. Their mutual dependence does not preclude conflicts. Free research puts social institutions under constant pressure to change. How do societies cope with the dynamics of modern science? They often try to restrict research, or to limit it to certain goals. But this puts the performance and reliability of science at risk. Even in democratic societies, citizens often know very little about what new scientific findings could mean for their lives. How can societies inform their members about science in such a way that they can realistically assess the opportunities it offers and the risks it entails? One of the interdisciplinary projects that has resulted from these questions aims to understand the interactions between the dynamics of science and the dynamics of society, in the past and in the present, in order to highlight points of convergence and divergence. To date, these interactions have been researched primarily in terms of the dangers and the opportunities of science-based technology. However, a society based on science is more than just a society based on technology – it is a society whose very core is oriented toward change.

THEORY AND MODELING

The natural and engineering sciences study the foundations of highly complex systems as well as their importance and functioning for their surroundings. These systems are anchored in various disciplines, such as materials science, physics, chemistry, and molecular and organismal biology, and the phenomena observed often cannot immediately be explained from first principles. On one hand, this requires theoretical innovations in basic research to better correspond to the importance of the complex system. On the other hand, the efficiency of today's computers makes it possible to simulate the behavior of complex systems and therefore to cross-reference simulation, experiment and theory to their mutual advantage. The topics addressed by the Max Planck Society exhibit a surprising convergence of issues and methods. Simulating molecular systems helps researchers to understand reactions on the surfaces of catalysts, as well as to model the structure and dynamics of biological macromolecules. Methods used in physics and the engineering sciences are increasingly making their way into the study of biological processes. Evolutionary theory attempts to understand biological systems as products of a historical optimization process.

NEW FRONTIERS IN THEORY AND MODELING

Computer-assisted modeling is taking on an ever greater role in modern research in the natural sciences, and has even developed into an independent scientific discipline over the years. Current research topics range from theoretical chemistry and various fields of the physics of condensed matter, to biophysics, turbulent plasmas and new aspects of bioinformatics. In the future, computer modeling will increasingly become a direct partner of experimentation, opening up completely new opportunities in experimental analysis. Novel methods and procedures can be expected particularly in the area of nanoscopically structured functional materials, such as hierarchically organized aggregates and proteins. In the future, it will also be possible to simulate entire systems. In addition, thanks to the increase in computing power, it is now possible to test many model and parameter variations without performing elaborate and, in some cases, even dangerous experiments. In this regard, modeling contributes not only to its actual task of providing insights, but also in very large measure to boosting research efficiency.



MPI of Plasma Physics/Frank Jenko

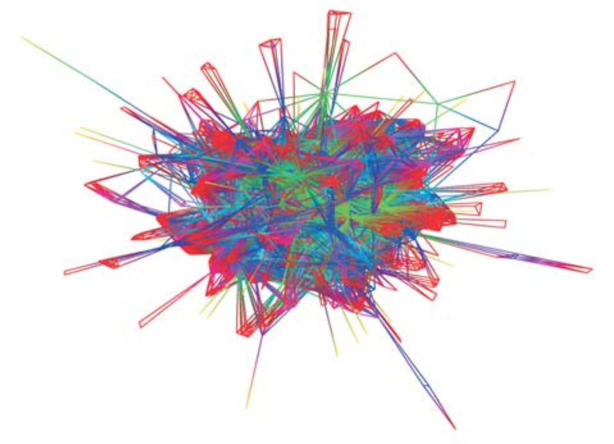
Three-dimensional kinetic turbulence simulation for a tokamak plasma: snapshot in a plane perpendicular to the magnetic field (linear dimension of the simulation domain corresponds to about 5 cm).

BIOLOGICAL NETWORKS AS COMPLEX SYSTEMS

The interactions of cell components, especially the genes and proteins, constitute complex networks. Research attempts to understand how their evolution and function are reflected in their architecture. This occurs, on the one hand, at the level of statistical network description, and, on the other hand, through modeling and simulation of a network's characteristics. The latter is the subject of systems biology, which combines theoretical analysis with experimentation and attempts to create, based on existing data, theoretical models for biological systems and their behavior. The understanding of the system properties of biological processes that is accomplished with this procedure has great implications for medical research. However, the understanding of complex biological processes is a great challenge for all of the natural sciences. The most exciting results are to be achieved through interdisciplinary cooperation, which will allow above all physicists, engineers and biologists to complement one another. Intense contact is needed between the biomedical institutes and the Chemistry, Physics and Technology Section (CPTS) in order to realize new breakthroughs.

PARTICIPATING INSTITUTES

- Fritz Haber Institute of the MPS, Berlin
- MPI for Astrophysics, Garching
- MPI of Biochemistry, Martinsried
- MPI for Biogeochemistry, Jena
- MPI for Biological Cybernetics, Tübingen
- MPI for Biophysical Chemistry, Göttingen
- MPI of Biophysics, Frankfurt/Main
- MPI for Chemistry, Mainz
- MPI for Computer Science, Saarbrücken
- MPI of Coal Research, Mülheim an der Ruhr
- MPI for Dynamics and Self-Organization, Göttingen
- MPI for Dynamics of Complex Technical Systems, Magdeburg
- MPI for Extraterrestrial Physics, Garching
- MPI for Iron Research, Düsseldorf
- MPI for Mathematics in the Sciences, Leipzig
- MPI for Mathematics, Bonn
- MPI for Metals Research, Stuttgart
- MPI for Meteorology, Hamburg
- MPI for Molecular Genetics, Berlin
- MPI for Polymer Research, Mainz
- MPI for the Physics of Complex Systems, Dresden
- MPI of Plasma Physics, Garching and Greifswald
- MPI of Quantum Optics, Garching



MPI for Molecular Genetics/Thomas Manke

Two proteins of a yeast proteome are considered joined in this picture when a physical interaction between them has been identified through experimentation. A higher-level organization appears as a network of many dense (red) associations.

SYSTEMS TECHNOLOGY AND COUPLED PROCESSES

The natural and engineering sciences are increasingly focusing on systems characterized by close coupling and networking of individual processes. Examples range from the design of modern industrial plants to the analysis of global material flows and biological systems. In most cases, looking at isolated parts is not sufficient, either qualitatively or quantitatively, to understand the behavior of the system as a whole. Therefore, a central aim of systems technology and its methodological basis, systems theory, is to develop analysis and design methods that facilitate treatment of these complete systems. In doing so, an approach is selected that allows widely differing processes to be analyzed with one and the same set of tools, through a mathematical description that is largely detached from any concrete application background. The expected social benefit is obvious: more efficient operation of modern production plants creates enormous ecological and economic advantages. It will be possible to better assess the consequences of anthropogenous interference in the global climate, or to shed greater light on diseases for which no cure has yet been found, and to develop and economically manufacture new drugs.

COMPUTATIONAL BIOLOGY AS A JOINT INITIATIVE OF THE CHINESE ACADEMY OF SCIENCES AND THE MAX PLANCK SOCIETY

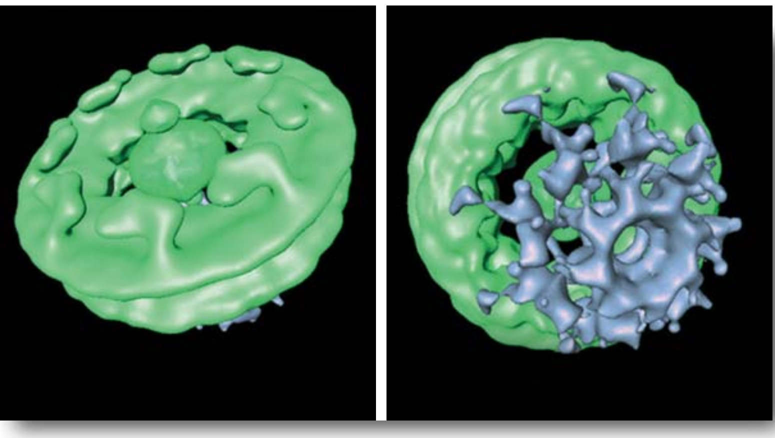
Computer-assisted theoretical biology, known as computational biology, has taken on a major role in the life sciences in recent years. The growing theoretical exploration of biology is expected to produce new and decisive impulses for the biomedical field. To promote this development, the Chinese Academy of Sciences and the Max Planck Society have resolved to establish a joint institute in Shanghai that will dedicate its research to theoretical and computational biology.

BIOLOGICAL STRUCTURES

The structures of living organisms are more varied and complex than those of inanimate matter. This applies to both the macroscopic organization of the living beings and the microscopic interaction between the large molecules that comprise them. In order to clearly understand the processes that take place in living cells, not only the precise spatial structure of the macromolecules must be known, but also how they interact in large assemblies and how they change with time. In principle, this task is nearly infinite – almost more so than, say, that involved in astrophysics. It has far-reaching consequences for how we view the world, and incalculable potential for the development of new medicinal agents, biocompatible materials and nanotechnology. Despite tremendous advances in the past 50 years, in many respects, science is still at the starting line when it comes to researching the biological universe. In the coming decades, it will, on the one hand, focus on clarifying the molecular foundations of key processes in living cells as thoroughly as possible. On the other hand, it must develop new methods for microscopic analysis and achieve a macroscopic understanding of biological structures. These two issues represent the main course of future biological structure research in the Max Planck Society.

STRUCTURAL BIOLOGY OF THE FUTURE

Structural biology is concerned with the spatial configuration of large molecules, and particularly with the proteins that make up all living organisms and enable them to live. The aim is to determine, if possible, the position of each individual atom in the proteins – a necessary, if not always sufficient, condition for understanding the precise tasks they perform within the organism. The structures of the building blocks of cells are determined using the complementary methods of protein crystallography, electron microscopy and NMR spectroscopy, all of which are used and continuously developed at the institutes of the Max Planck Society. In addition to the physical methods for experimental structure determination, numerical methods are playing an ever greater role in structural biology. Using the experimentally determined structures of the macromolecules as a starting point, it is possible, in principle, to simulate the chronological and spatial changes that are key to understanding their function. Particular attention is also being paid to biological and medical issues that elude the routine methods of hypothesis-free research. The clarification of the structure and action mechanism of key proteins and their associations will continue to occupy those involved in basic research in the Max Planck Society for a long time to come.



MPI of Biochemistry/Wolfgang Baumeister

The three-dimensional structure of the nuclear pore of the slime mold Dictyostelium: the 3D image makes it easy to distinguish between, on the one hand, the filamentous protrusions and the various rings of the nuclear pore that form the central transport channel, and on the other hand, the basket-like structure.

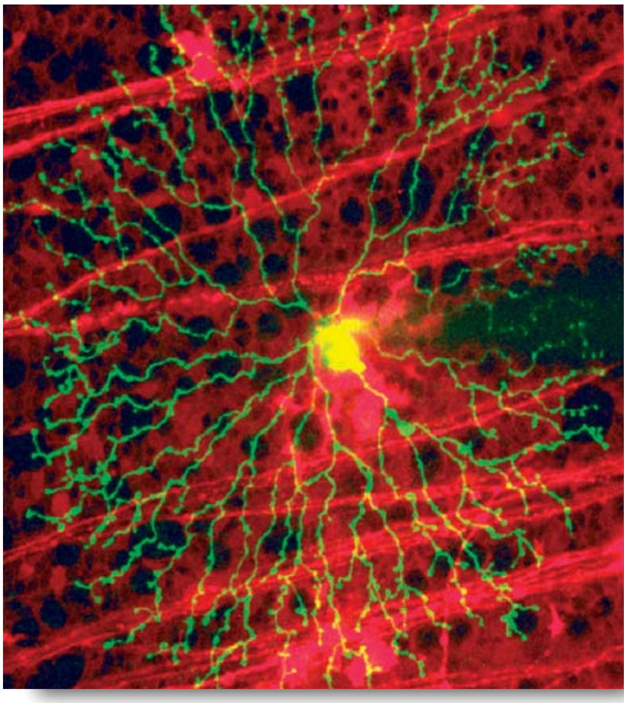
THE STRUCTURES OF LIFE

Living beings of all stages of development are characterized by the complexity of their spatial structure. This structure determines the physiological function of the organism, and the function likewise determines the structures. Consequently, more than any other scientific discipline, biological research depends on the development of imaging methods on all length scales – from the atomically resolved structures of biological macromolecules to the satellite-based mapping of entire biotopes. Particularly when attempting to clarify physiological mechanisms, due to the close interrelationship between structure and function, special importance attaches to those processes that

PARTICIPATING INSTITUTES

- Max Planck Research Unit for Structural Molecular Biology at DESY, Hamburg
- MPI of Biochemistry, Martinsried
- MPI for Biological Cybernetics, Tübingen
- MPI for Biophysical Chemistry, Göttingen
- MPI of Biophysics, Frankfurt/Main
- MPI for Brain Research, Frankfurt/Main
- MPI for Developmental Biology, Tübingen
- MPI for Dynamics and Self-Organization, Göttingen
- MPI for Experimental Medicine, Göttingen
- MPI for Medical Research, Heidelberg
- MPI for Molecular Cell Biology and Genetics, Dresden
- MPI of Molecular Physiology, Dortmund
- MPI of Neurobiology, Martinsried
- MPI of Quantum Optics, Garching
- MPI for Terrestrial Microbiology, Marburg

record spatially resolved information in all three dimensions in living organisms. Compared with the modern methods of magnetic resonance imaging and electron tomography, light microscopy is one of the oldest methods known in the life sciences. It has retained – and even augmented – its importance for biology, as it is the only method that allows observation of living organisms with both high spatial and time resolution. Especially the observation of changing structures is important for recognizing functional relationships between actions. As the key method in this field, light microscopy is continuously incorporating new technologies, such as laser light sources, high-sensitivity detectors and single-molecule sensors. This development is by no means complete, and is being further advanced at the Max Planck Institutes.



MPI for Medical Research/Winfried Denk

Two-photon fluorescence image of a starburst amacrine cell (green) of an intact retina. The cell is filled with the calcium indicator Oregon Green BAPTA-1. The red areas result from an injection of sulforhodamine for color contrast.

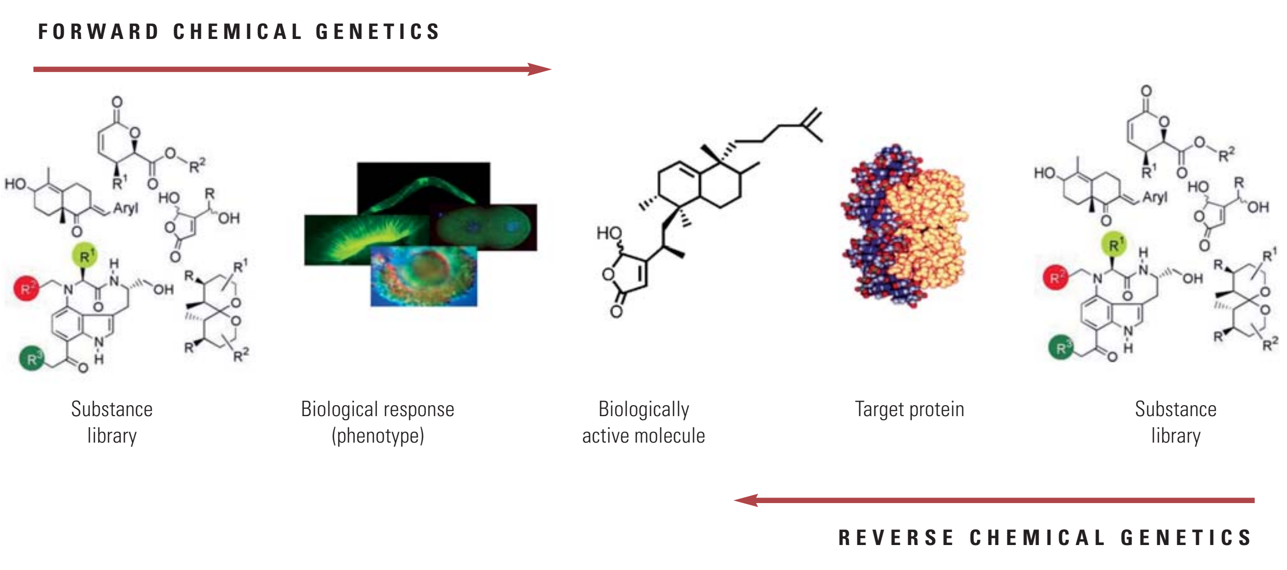
HEALTH

In the future, biomedical basic research will increasingly provide scientific solutions to urgent health issues, such as difficult-to-treat infectious diseases in Africa and Asia and the increasing number of age-related illnesses. Thanks to advances in biotechnology and bioinformatics, the highly specialized skills that have been developed in the natural sciences can now be networked with clinical research. At present, stem cell research, more than any other biomedical field, is the subject of strong controversy. This approach, however, can help us determine how to treat – and possibly even heal – diseases caused by pathological cell destruction. Furthermore, infection biology enables particularly impressive insights into the interplay between the human organism and potentially harmful factors. Transferring findings from basic research to practice is difficult, not least because of the differing scientific backgrounds of those who practice medicine in a clinical environment and those who conduct lab research. To optimize this bi-directional process between the hospital bed and the laboratory, the Max Planck Society has developed several models for knowledge transfer. The example of depression research shows, how a successful dialog can develop between medical experts doing basic lab research and those working with patients.

CHEMICAL GENOMICS

In chemical genomics, highly specific molecule probes are used as powerful tools for biological and biomedical research. These small, biologically active chemical substances can be found in nature's own reservoir or through combinatorial chemistry. On the one hand, this combination of chemical and biological methods paves the way for brand new opportunities for basic research in the biosciences. On the other hand, it may have a profound impact on implementing the resulting findings in potential applications. The substances identified through chemical genomics facilitate a systematic analysis of entire cells and organisms with a view to the medical relevance of biological research more effectively than purely genetic and molecular biological methods. When the biological effect has been adequately studied and validated in terms of its therapeutic relevance, the low molecular substance can serve as a similarly biologically validated reference structure for developing potential active substances. Several Max Planck Institutes are working together to develop such molecular probes for biological analyses.

In chemical genetics, a screening process is used to analyze a molecule library in terms of its biological activity. If a substance produces an interesting biological effect, the corresponding target protein can be identified. Conversely, the biological significance of a protein identified through genome research can, in conjunction with a molecule library, identify a ligand that binds to that protein. This allows studies to be carried out – either in living cells or in model organisms – that show what function the protein has.



MPI of Molecular Physiology/Herbert Waldmann, Rolf Breinbauer

PARTICIPATING INSTITUTES

- MPI of Biochemistry, Martinsried
- MPI for Biophysical Chemistry, Göttingen
- MPI of Coal Research, Mülheim an der Ruhr
- MPI for Experimental Medicine, Göttingen
- MPI for Extraterrestrial Physics, Garching
- MPI for Heart and Lung Research, Bad Nauheim
- MPI of Immunobiology, Freiburg
- MPI for Infection Biology, Berlin
- MPI for Molecular Biomedicine, Münster
- MPI of Molecular Cell Biology and Genetics, Dresden
- MPI of Molecular Physiology, Dortmund
- MPI of Neurobiology, Martinsried
- MPI for Plant Breeding Research, Cologne
- MPI of Psychiatry, Munich

THE IMPORTANCE OF BASIC RESEARCH FOR STEM CELL THERAPY

Until a few years ago, the term stem cell was all but unknown among the general public. Since then, it has become a magic formula that is expected to produce innovative treatment methods, but that also meets with considerable skepticism. It is estimated that nearly half of all humans could benefit from stem cell research – and the hopes of those who are directly and indirectly affected are high. The discussion on researching and using human embryonic stem cells is controversial because of the therapeutic promise, on the one hand, and the use of embryos on the other. What potential do adult and embryonic stem cells offer for therapeutic use? Only basic research in conjunction with suitable animal models can answer this question, by facilitating an understanding of the characteristics of adult and embryonic stem cells at the molecular level. Only then will it be possible to tap their respective potential and develop new therapeutic approaches. This subject area is not only one of the most interesting in basic biological research today, it also holds immense therapeutic potential.

THE DIALOG BETWEEN BASIC RESEARCH AND MEDICAL APPLICATION

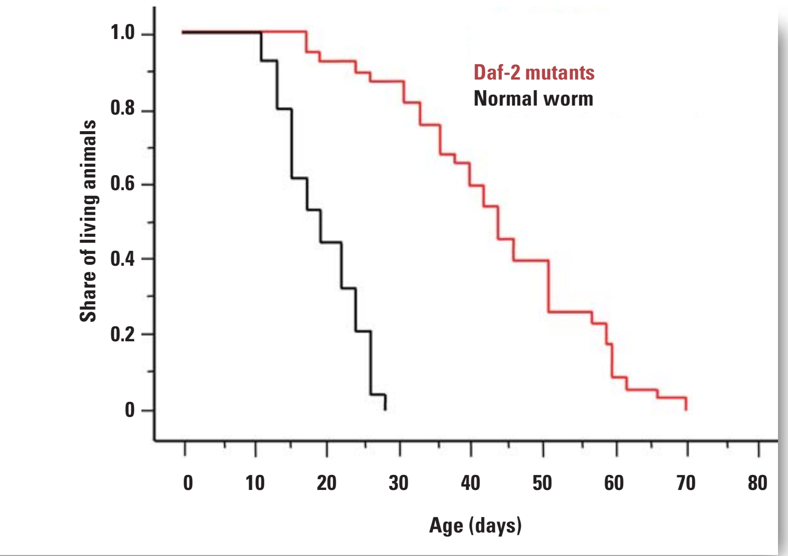
Medicine's greatest future task is to bring the health span closer to the life span through disease prevention. New analysis strategies are needed to link the detailed knowledge that has already been acquired in many Max Planck Institutes so that basic research and therapy research can bolster one another. The Max Planck Society is confronted with the great challenge of redefining its scope of tasks at the interface between basic research and clinical application. This is important because, in a society whose average age is increasing and whose birth rate is decreasing, issues relating to the health status of its population are high on the political agenda. Today, the public is concerned about the cost of recovering from illness. Tomorrow, the task will be to determine what must be done to ensure that ever more – and ever older – people remain productive enough to hold their own socially, culturally and materially in the global community. The great tasks for the future of medicine can be successfully accomplished only by transferring research from the clinic to the laboratory and back. The Max Planck Society is well equipped to design the navigation system for future medical research.

MPI of Psychiatry/Isabella Wieser

At the MPI of Psychiatry, research is transferred directly from the clinic to the lab, and vice versa.

AGING: BIOLOGY AND CULTURE

One of the most striking changes in industrialized societies and the third world is that their aging populations are living longer and societies are reaching a higher average age than before. The search for the reasons behind these changes leads to the question of what actually causes aging. What are the genetic contributions to aging? How can diseases in the elderly be detected at an early stage and treated more effectively? How can physical and mental abilities be maintained into old age? How must society change to better bring the productivity of its older members to bear? The Max Planck Society has recognized the importance of gerontology, the science of aging and age, and has already been successfully promoting aging research for decades at several institutes. Moreover, the Max Planck Society has established two new research initiatives to further support research into aging: the founding of a new institute to examine the biological basis of aging, and MaxNet Aging, an international network for aging research in the behavioral and social sciences and the humanities.

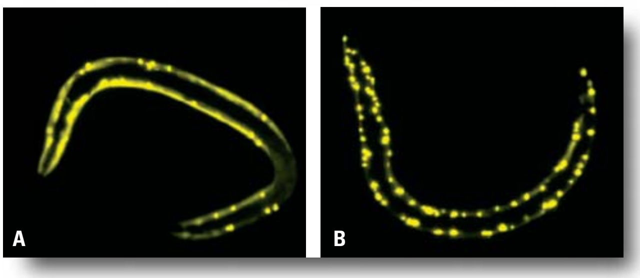


Survival curves of normal threadworms (black) compared with animals whose lifespan is extended through a mutation in the daf-2 gene (red). The mutated animals live on average twice as long as normal worms.

Modified after Dorman, J. B. et al.

THE BASICS OF THE BIOLOGY OF AGING – ESTABLISHING A NEW INSTITUTE

Biological aging is a normal process that is controlled, at least in part, by genetic programs. In complex interaction with exogenous influences, it leads to increased susceptibility of the organism to chronic diseases. In view of the demographic development in industrialized countries, the typical diseases of human aging are the topics for intensive research. Still, little is known about the basic genetic and biochemical mechanisms of aging. To facilitate an interdisciplinary approach to researching these processes, the Max Planck Society is planning to establish an institute for the biology of aging. The resident research groups there will compare evolutionarily distinct model organisms with varying degrees of complexity and similarity to humans. This will be supplemented by studies on human cells in culture, as well as a biochemical analysis of the molecular changes that characterize aging. The long-term goal will be to understand the requirements for healthy human aging and to extend the healthy human lifespan by acquiring a thorough understanding of the molecular processes of aging.



Microscopic images of two threadworms of the same chronological age, in whose muscle cells protein clumps (aggregates) were detected (yellow stain). The animal in photo A carries a life-prolonging mutation and exhibits only a few aggregates. The muscle cells of the normally aged animal, on the other hand (photo B) contain many aggregates, which result in marked motor paralysis.

Northwestern University, Evanston, USA/Richard Morimoto

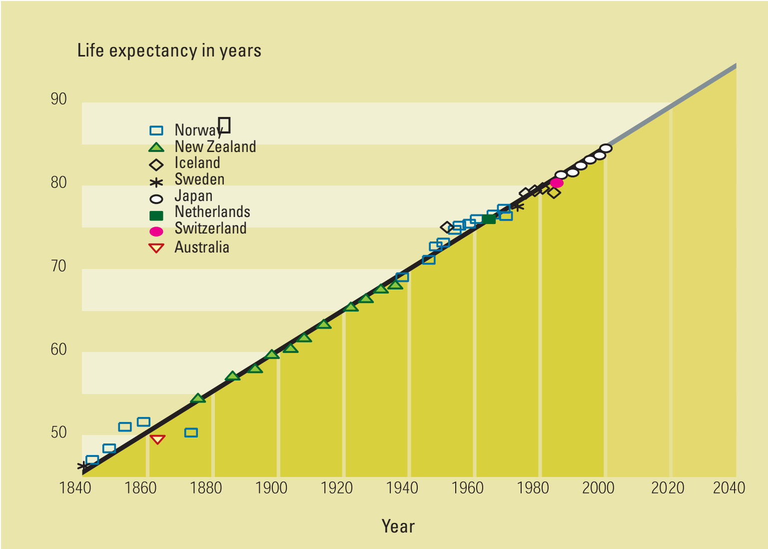
PARTICIPATING INSTITUTES

- MPI of Biochemistry, Martinsried
- MPI for Demographic Research, Rostock
- MPI for Evolutionary Anthropology, Leipzig
- MPI for Human Cognitive and Brain Sciences, Leipzig and Munich
- MPI for Human Development, Berlin
- MPI for Molecular Genetics, Berlin
- MPI of Psychiatry, Munich

And other institutes of the MPS and its international partners

INTERNATIONAL MAX PLANCK RESEARCH NETWORK ON AGING

Research on aging is an important scientific and social concern that requires interdisciplinary cooperation between experts from various fields. By establishing an international Max Planck research network for aging research (MaxNet Aging), the Max Planck Society is turning the spotlight on aging as an individual and societal phenomenon. The network will offer leading international scientists and institutions in various areas of aging research the opportunity to collaborate to define interdisciplinary questions and coordinate research activities. At the same time, the network will give outstanding young researchers the chance to address innovative and interdisciplinary issues of aging research in an international environment. Finally, in creating this network, the Max Planck Society is testing a new instrument for research promotion in order to flexibly and effectively determine key focus areas and open up new fields of research.



Aging as an opportunity: MaxNet Aging puts the focus on researching aging as an individual and social phenomenon.

MPI for Demographic Research, James W. Vaupel

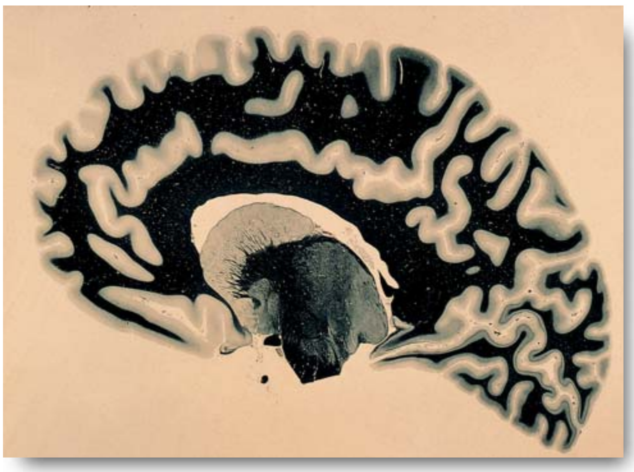
THE COMPLEX NETWORK OF THE BRAIN

Brain research is a courageous undertaking, as the human brain is the most complex structure in the universe. But brain research also seems to be a contradiction in itself – how can a human brain fathom itself? In addition, brain research raises questions regarding humans' understanding of themselves: what is consciousness? How are we to understand the body-soul problem? And how do the brain and intellect develop? Brain research is extraordinarily important for helping people with neurological and psychiatric disorders. In recent decades, neuroscience has gained enormous momentum worldwide. The Max Planck Society, too, has expanded into neuroscience and has established several new institutes in this field, such as the Max Planck Institutes for Biological Cybernetics, of Neurobiology, for Neurological Research, for Psychology Research, for Human Cognitive and Brain Sciences, and for Psycholinguistics. The individual institutes pursue neuroscience from its molecular principles to cognition. Three areas on which future research will focus are presented in more detail: how does the brain develop, what is defined by genes and what is imprinted by experience and learning? How can we investigate cognitive functions, what do findings from animal experiments contribute to our understanding of the human brain and how can we analyze cognitive processes and higher brain functions in humans? And regarding brain functions and aging, how does intellectual performance differ between youth and old age?

THE DEVELOPMENT OF THE BRAIN

The human brain – with its billions of nerve cells connected by innumerable paths, circuits and synapses – develops from a single fertilized egg cell. The nerve cells of the brain are formed in specific growth zones, from where they then migrate to their target region. There, they settle in specific brain areas and strata and differentiate into various classes and types of neurons. Nerve cell processes, so-called dendrites and axons, grow and form precise connections between different brain areas and neurons. Finally, synapses form between the connected nerve cells, and the brain is ready to function. However, it is not yet mature. It does not reach its full performance capacity until it interacts with the environment, through experience. These stages of brain development will be studied more intensively in future Max Planck Society projects.

MPI for Brain Research/Heinz Wässle



COGNITIVE NEUROBIOLOGY

Until recently, systems neuroscience relied almost exclusively on electrophysiological studies. While the technology applied was useful for characterizing the physiological properties of individual neurons, this method cannot gather information on the space-time cooperativity and the full range of association processes of neural networks. The future of systems neuroscience depends on the development and application of integrative methods. In the future, recordings with multielectrode arrays, observation of slow brain waves, and brain imaging methods must be used to find out how the brain generates various behaviors. Imaging technologies are extremely important in this endeavor.

NEUROCOGNITION: COGNITIVE PROCESSES AND HUMAN BRAIN FUNCTIONS

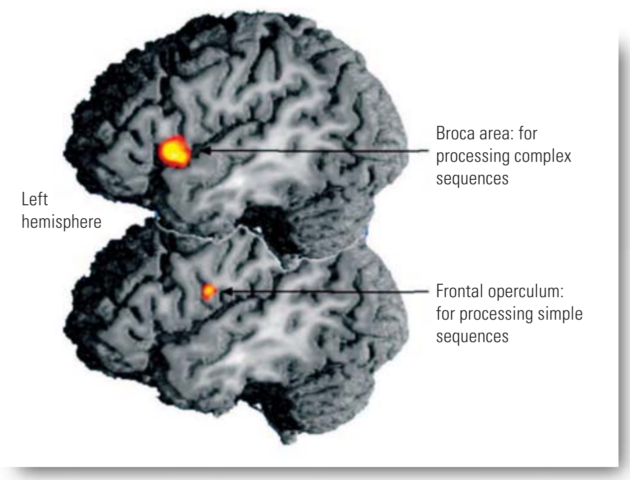
In recent years, the development of new methods has made it possible to study human cognitive activities and the underlying brain processes in ever closer correlation. Cognitive processes such as perceiving, understanding, remembering, thinking or deciding have always been analyzed using psychological research methods, which are based on experimental analysis of behavior and experience. These methods have now been refined to such a degree that researchers can break down complex cognitive

This image shows a longitudinal section through a human brain. The stained portion (black) is not the nerve cells of the brain, but the fibers that connect them. One cubic millimeter of tissue contains more than one kilometer of fibers. The entire brain is wired with fiber strands totaling about one million kilometers in length.

PARTICIPATING INSTITUTES

- MPI for Biological Cybernetics, Tübingen
- MPI for Biophysical Chemistry, Göttingen
- MPI for Brain Research, Frankfurt/Main
- MPI for Computer Science, Saarbrücken
- MPI for Demographic Research, Rostock
- MPI for Dynamics and Self-Organization, Göttingen
- MPI for Evolutionary Anthropology, Leipzig
- MPI for Experimental Medicine, Göttingen
- MPI for Human Cognitive and Brain Sciences, Leipzig and Munich
- MPI for Human Development, Berlin
- MPI for Medical Research, Heidelberg
- MPI for Molecular Genetics, Berlin
- MPI of Neurobiology, Martinsried
- MPI for Ornithology, Seewiesen
- MPI for Psycholinguistics, Nijmegen
- MPI for Social Anthropology, Halle/Saale

activities into individual sub-processes, characterize them in terms of time and function, and draw conclusions therefrom about the mechanisms on which they are based. Even more spectacular are the latest methods developed in the field of brain research: today, imaging methods based on registering the electrical and magnetic phenomena that accompany brain activity make it possible to observe the brain while it performs cognitive activities, and to track the spatial and chronological distribution of activation processes (especially EEG, MEG and fMRI). These are supplemented by interference methods that can target and disrupt circumscribed brain processes (TMS). This opens up fascinating perspectives for researching the relationship between cognitive activities and brain processes.



MPI for Human Cognitive and Brain Sciences/Angela Friederici et al.

Modern neurocognitive research looks at how cognitive processes are related to processes in the brain. In this way, it creates a new empirical basis for answering the old philosophical question of how intellectual processes accompany material processes in the brain.

HUMAN MENTAL DEVELOPMENT ACROSS THE LIFE SPAN: PERSONALITY AND DECISION-MAKING COMPETENCE

In human mental development, biological and socio-cultural systems intertwine. Interaction with the social environment is required for early behavior competence to form and for the brain to mature. Investing biological potential makes it possible to acquire bodies of cultural knowledge. In advanced adulthood, abilities based on biological factors decline, while those based on acquired knowledge remain stable or even improve with age. Max Planck Institutes are studying the interaction of cultural and biological systems from embryogenesis into old age, with the aim of investigating the principles of personality and the prerequisites for competent decision-making. The areas of focus include searching for links between age changes in brain and behavior, optimizing intellectual and emotional productivity in old age, and the role of technology in an aging-friendly society.

Taking electrophysiological measurements with an electroencephalogram (EEG) allows researchers to capture age differences in neuronal correlates of learning. They have a high temporal resolution and are particularly suitable for mapping developmental changes in brain activity.

SOCIAL ORDER IN A GLOBAL WORLD

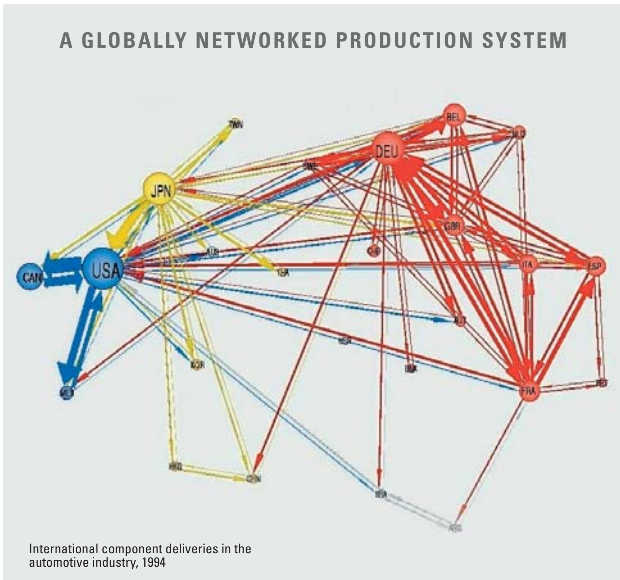
The rapid spread of social structures beyond national boundaries is creating a critical need for new transnational orders. The globalization process is outpacing the formation of supra-governmental institutions that could organize and govern the new social, economic and cultural relationships that transcend nations. National systems continue to exist within the framework of the developing international regime, but they are coming under strong pressure to adapt, and the outcome is uncertain. There are numerous and diverse points of tension between national and international institutions. The integration of national societies into the emerging global society appears as a process of both adaptation and differentiation. At the same time, the internal diversity of national societies is increasing as a result of international migration. Previously unknown problems of social integration are appearing, not only at the global level, but also within individual nations, which are increasingly unable to maintain external boundaries. Such problems are manifested, for example, in new forms of transnational crime and political violence.

SOCIAL AND PERSONAL INTEGRATION IN CULTURALLY HETEROGENEOUS SOCIETIES

The borders of Europe's prosperous societies are becoming more permeable. Increasing international migration is calling traditional forms of social integration into question – not least because they are also being rejected by many immigrants who do not want to give up their ties to their home countries. As a result, the cultural heterogeneity of European societies is growing. This offers manifold opportunities, as the history of heterogeneous societies shows. At the same time, however, very basic conflicts are emerging, for example over how to deal with religion in the public sphere. If social cohesion is to be ensured, politics and law must find answers to the novel opportunities and risks of cultural heterogeneity. The changing make-up of developed European societies raises a number of empirical, analytical and normative research issues. Addressing them calls for the joint efforts of historians, psychologists, sociologists, demographers, political scientists and scholars of law.

GLOBALIZATION: NATIONAL STATES IN A GLOBAL SOCIETY

Globalization and internationalization are giving rise to new forms of global integration and to both convergence and differentiation between national societies. Active adaptation to a globally integrated economy that can less and less be understood as the sum of essentially independent economies often demands deep intervention in mature systems of social security, of regulating the labor market, of education and training, of financing public tasks, of corporate governance and of regulating banking and finance. Thus internationalization is forcing radical changes in the structure and function of politics and law in existing nations. One example is European integration, with its interplay between the formation of new supranational regimes and the often painful adaptation of national institutions. Numerous Max Planck Institutes are working on the prerequisites for and the consequences of this development.



MPI for the Study of Societies/Lothar Krempel

The automotive industry is one of the most highly globalized sectors of the economy. Global sourcing links manufacturers on five continents in a worldwide production system.

PARTICIPATING INSTITUTES

- Bibliotheca Hertziana – MPI for Art History, Rome
- MPI for Comparative Public Law and International Law, Heidelberg
- MPI for European Legal History, Frankfurt/Main
- MPI for Foreign and International Criminal Law, Freiburg
- MPI for Foreign Private and Private International Law, Hamburg
- MPI of History, Göttingen
- MPI for Intellectual Property, Competition and Tax Law, Munich
- MPI for Social Anthropology, Halle/Saale
- MPI for the Study of Societies, Cologne

Research topics include the reform of national welfare states, the functional requirements for international markets, the Europeanization of private law, questions of social security and political stability in a globalized economy, demographic developments in Europe in a changing political environment, and the ability of nationally organized democracy to function in an internationalized economy.

Workshop "Islamic and Constitutional Law". On the podium (fltr): Dr. N. Yassari (MPI Hamburg), PD Dr. R. Grote (MPI Heidelberg), Dr. S. Fayez (Minister for Higher Education), A.R. Karimi (Minister of Justice), Prof. Dr. B. Akhlaghi (University of Teheran), Z.M. Hashemi (Afghan Embassy, Berlin).

TERRORISM, WAR AND POLITICAL VIOLENCE

Controlling terrorism, organized crime and war crime are central issues of a new security debate. Of particular interest is the distinction between terrorism and other forms of crime and violence. The focus here is on the transnationality of spaces, targets and conflict lines of terrorism, the organization of criminal capital formation in the broadest sense and the classification of different forms of violence. The institutes of the Max Planck Society offer an ideal interdisciplinary platform for addressing the issues raised in the new security debate. The legal sciences are studying the formal control of political violence and war. The social and behavioral sciences are working on the differentiation and classification of conflicts and conflict risks, the organizational forms of terrorism and organized crime, violence in modern societies, and the ethnological conditions and consequences of conflicts and conflict settlement. Historians of culture and law are investigating the continuities and discontinuities of controlling political violence and war.

MARKETS AND INSTITUTIONS

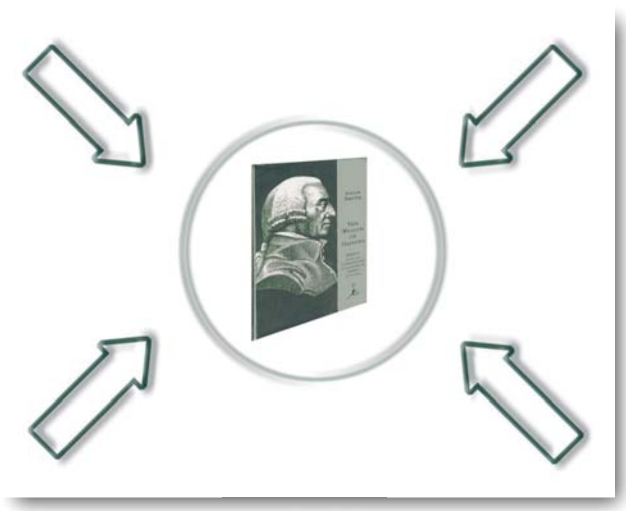
The collapse of planned economies in the 1990s and the success of the free-market economy in industrialized countries made it appear that the market is the natural economic control mechanism. In reality, however, markets can function only under specific conditions that, by and large, elude quick availability. These include effective and efficient legal systems and government structures in whose fairness and efficacy those operating in the market can trust, as well as a culture in which individuals understand themselves to be acting on their own responsibility. Globalization, driven by the worldwide triumph of the market economy, has added a new international and intercultural complexity to the dynamic triangle of market, law and culture. Unlike in nationally and regionally confined markets in the past, competition is no longer restricted to goods looking for buyers, but extends to entire social and economic systems competing with each other. Several institutes in the Humanities, Social and Human Sciences Section of the Max Planck Society are working on the intersection between markets, laws and cultures. In this way, they are contributing to our understanding of market mechanisms that produce an efficient distribution of resources and thereby create national and global wealth.

THE VISIBLE AND INVISIBLE PREREQUISITES FOR THE INVISIBLE HAND

Markets control behavior with an invisible hand. The common good is the sum of the individual egoisms. Citizens of western industrial nations have become quite accustomed to these seemingly paradoxical statements. They see that it works on a daily basis. And they have seen that centrally planned economies have failed miserably. Yet, in these countries the Western recipe is often working less well for the time being. Apparently, the simple explanations for the power of markets are too simple. The working of the invisible hand is conditional on visible and invisible prerequisites. The proper organization of markets is an urgent and rewarding subject for a science of institutional design. Several institutes of the Max Planck Society are addressing the basic social, psychological and legal conditions for functioning markets.

INSTITUTIONS FOR *HOMO SAPIENS*

Institutions are made for people. More yet: institutions are only meaningful because they influence human behavior. No one can prevent a storm. But people can be persuaded to reduce their carbon dioxide emissions and thus counteract the warming of the planet. That is why institutional design begins by reconstructing the problem at issue as one of behavioral change. A prediction is then made about how the institutional intervention will change behavior. Will addressees even notice the change? What adaptative response can be expected? How widely will responses vary? If institutional design requires a psychological foundation, the ambitious goal must be to design institutions based on behavioral science. To this end, cooperative efforts among Max Planck institutes will seek answers to questions such as: what is the implication for the impact of law if those subject to the law are nearly always guided by simple heuristics? How can institutions take advantage of the amazing ability of the human brain unconsciously to process large quantities of data? How do people behave in environments characterized by an abundance of institutions – for instance, in the medical and legal professions?



Adam Smith and the invisible hand of the market.

PARTICIPATING INSTITUTES

- MPI for Brain Research, Frankfurt/Main
- MPI for Comparative Public Law and International Law, Heidelberg
- MPI for Demographic Research, Rostock
- MPI of Economics, Jena
- MPI for Foreign and International Criminal Law, Freiburg
- MPI for Foreign and International Social Law, Munich
- MPI for Foreign Private and Private International Law, Hamburg
- MPI for the History of Science, Berlin
- MPI for Human Cognitive and Brain Sciences, Department of Psychology, Leipzig and Munich
- MPI for Human Development, Berlin
- MPI for Intellectual Property, Competition and Tax Law, Munich
- MPI for Research on Collective Goods, Bonn
- MPI for Social Anthropology, Halle/Saale
- MPI for the Study of Societies, Cologne

OWNERSHIP AND COMPETITIVE SYSTEMS AS A STRUCTURAL PREREQUISITE FOR ECONOMIC DEVELOPMENT

How should the natural and human resources of the global community be used? Answering this question requires more than just scientific and economic expertise. The core prerequisite for increasing global welfare and distributing goods fairly is a legal system. That is what makes it possible for nations and their enterprises and citizens to organize productive utilization through rights of disposal and exchange of goods. Decisions to be made include: should the government or should citizens perform certain economic tasks – for example services for the public? How to structure private rights so that they do not inhibit but rather promote innovative activity? Who benefits from free access to competition? What beneficial or harmful influence does taxation have on the free play of economic forces? How long will private business continue to finance government welfare systems? Only when the complex concert of legal instruments is fully understood – also from an economic and social science perspective – can assertions be made about the future structure of our economic system. The institutes of the Max Planck Society study the national and international development of ownership and competing regimes and devise basic models for coordinated legislation. Joint projects develop future prospects for government regulation, for example on the future of taxation and welfare systems in competition, or on the basic legal conditions for high technology.

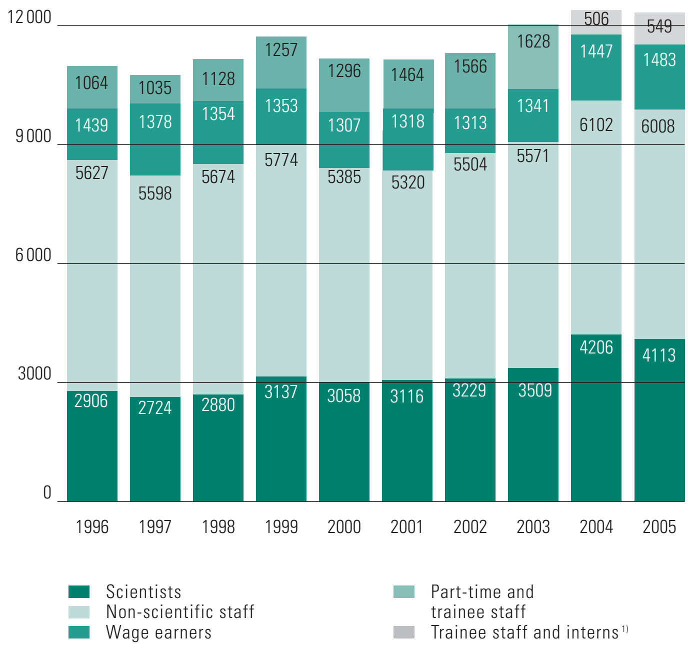
dpa-Fotoreport

In Bangkok, farmers and opponents of globalization demonstrate against the planned WTO conference in Cancun in 2003.

FACTS AND FIGURES – THE MAX PLANCK SOCIETY

SMALL BUDGET, STRONG PERFORMANCE

78 institutes and 12,153 members of staff, a budget of 1.322 billion euros in the year 2005, which is a figure on par with the budget of two larger universities.



1) Changes compared to previous year: staff employed on a part-time or temporary basis are no longer listed as a separate group in the employee statistics, but are included in the relevant employee category.

EXCELLENCE AS HALLMARK

16 Nobel prizes and 30 Leibniz prizes.

PACESETTER IN RESEARCH

12,500 publications in the specialized press during 2004, representing one third of all contributions from Germany in Science and Nature – the worldwide leading science magazines.

CURRENT LISTING OF THE INSTITUTE OF SCIENTIFIC INFORMATION

54 Max Planck scientists are among the most frequently quoted worldwide – other German research organizations can only claim a maximum of four scientists on this list.

INNOVATIONS FOR THE ECONOMY

More than 2,300 inventions and just under 1,400 exploitation contracts; exploitation revenue: 168 million euros; foundation of 65 companies with 2,500 jobs since 1990.

POPULAR EMPLOYER

The number 1 preferred employer among natural science and engineering students and number 2 among engineers – behind Siemens and ahead of DaimlerChrysler (BIZZ, 2000); worldwide one of the 30 "best employers for post docs" (Internet survey The Scientist, 2003).

BRAIN GAIN

Every fourth director position is internationally staffed, in the new Federal States a full 60 percent of such posts, while 50 percent of the junior scientists come from foreign countries.

Junior and Visiting Scientists in 2003	Germans	Foreigners	Total
Student assistants	2,257	–	**2,275**
Bachelors	–	93	**93**
Ph.D. students	2,048	1,865	**3,913**
Post-doctoral students	390	1,943	**2,333**
Research fellows	–	964	**964**
Visiting scientists	295	548	**843**
Total	**5,008**	**5,413**	**10,421**

HIGH STANDING

Throughout Germany, the Max Planck Institutes enjoy the third highest standing of key German institutions – after the Bundesbank and the Federal Constitutional Court (Allensbacher Führungskräfte-Panel,1995).

	Total	Perc. of women	Institution. funding	Project-funding
Directors and Scientific Members	269	4.5%	269	–
Senior research scientists	158	21.5%	156	2
Heads of Independent Junior Research Groups	34	17.6%	33	1
Academic staff	3,652	23.7%	2,529	1,123
Total number of scientists [1]	**4,113**	**22.3%**	**2,987**	**1,126**
Technical staff	3,405	44.8%	3,177	228
Administrative staff	1,556	73.7%	1,531	25
Health care staff	123	72.4%	122	1
Other services	924	89.4%	908	16
Total of non-scientific staff	**6,008**	**59.7 %**	**5,738**	**270**
Wage earners	**1,483**	35.2%	1,470	13
Total (scientists + non scientific staff + wage earners)	**11,604**	**43.3%**	**10,195**	**1,409**
Trainee staff	526	35.2%	526	–
Interns	23	34.8%	19	4
Total number of employees	**12,153**	**43.0%**	**10,740**	**1,413**

Employees in the Max Planck Society on January 1, 2005

Nationality of foreign junior and guests scientists

SITES OF THE RESEARCH INSTITUTIONS WITHIN THE MAX PLANCK SOCIETY

For further information see: **www.mpg.de**

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