# Max Planck Institute for Marine Microbiology

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MAX-PLANCK-GESELLSCHAFT

# Contents



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# Editorial

For two thirds of earth's history, microorganisms dominated our planet and developed complex biota in the oceans and inland waters. In the course of nearly four billion years of evolutionary history, prokaryotic organisms, in other words bacteria and archaea, have evolved a great metabolic diversity.

Managing Director
Prof. Dr. Rudolf Amann

To this day, microorganisms are primarily responsible for catalyzing diverse decomposition processes of organic and inorganic substances. They play a key role in controlling global element cycles and thereby help keep our planet inhabitable. They also ensure that almost all waste products are decomposed and recycled in the oceans, so that toxic compounds do not accumulate and endanger fauna or flora.

Although marine microbiology is not a new field of research, our knowledge of marine microorganisms and their functional importance remains incomplete. Only about one percent of all species of microorganisms are known today, and new species with new capabilities continue to be discovered. Examples of such discoveries include the symbiosis between archaea and bacteria that decompose the greenhouse gas methane deep down in the ocean floor with the help of sulfate. This key process in the global carbon cycle has long been known about, but the microorganisms involved were only recently identified. Another example is anaerobic ammonium oxidation (anammox) with nitrite or nitrate – a newly discovered process that may constitute the most important nitrogen sink in the oceanic nitrogen cycle. The anammox microorganisms responsible for this process were first discovered in an industrial waste treatment plant in the early 1990s. The successful search for bacteria with similar metabolic potential in the ocean has fundamentally changed our understanding of the marine nitrogen balance.

These examples show how field research on marine processes and laboratory research on microorganisms combine to advance our knowledge of element cycles and the conditions for life. At the Max Planck Institute for Marine Microbiology, microbiologists, molecular biologists and biogeochemists work together to understand basic principles of marine microbial ecology. Our focus lies on the anaerobic (oxygen-free) world below the sediment surface, because this is where many interesting and hitherto unknown life forms exist that play a crucial role in the coupling of element cycles – and hence in the chemistry of the oceans. The researchers at the institute cover a broad range of disciplines and areas of expertise, from microsensors to microbiology, from geochemistry to genome analysis, and from molecular ecology to mathematical modeling.

The aim of this brochure is to convey our perspectives of this exciting research field and to present the work carried out by scientists and other staff at the Max Planck Institute for Marine Microbiology in Bremen.

Sincerely,

R. Amann

# The Max Planck Institute for Marine Microbiology

What we know is a drop;
what we don't know is an ocean.
*Isaac Newton*

And what we know about oceans is a drop.

## Diversity

They are inconspicuous yet omnipresent, only a few thousandths of a millimeter in size and yet the real rulers of the world, they live underground yet influence the global climate right up to the upper layers of the earth's atmosphere: 'they' are the microorganisms in the oceans –and the research targets of the Max Planck Institute for Marine Microbiology (MPI) in Bremen. Scientists at the institute endeavor to isolate and cultivate new microbial species, because only one species in a hundred has been identified so far. They study the marine habitats of these unicellular organisms, the prokaryotes, primarily in sediments of the ocean floor, but also in mud volcanoes, sponges and hard corals, and in the water column. Their aim is to discover all that microorganisms can do and bring about.

## Role

MPI staff analyze how marine microbes convert substances and what these processes signify for the global element cycles of carbon, sulfur, nitrogen and iron. They concentrate, on the one hand, on those highly important reactions that have already been discovered, including the anaerobic oxidation of methane (AOM), anaerobic ammonium oxidation (anammox) and the reduction of sulfate; on the other hand, they look for new, hitherto unknown metabolic pathways. Their efforts are also aimed at discovering how prokaryotes have adapted to their environment and respond to changes, and the effects of all this on their habitat, the earth and the climate.

Where research was and is performed

## Characteristics

The research staff at the MPI also study the unique and fascinating characteristics of single species, such as nitrate-storing vacuoles in large sulfur bacteria. The study of microorganisms necessitates the application of some very diverse equipment ranging from special microsensors and mass spectrometers to deep-sea robots and large research ships. The effort and expense involved is anything but minimal: the scientists participate in seagoing expeditions, carry out experiments and extensive data analyses, they write and read specialist publications and participate at conferences; engineers and technical staff develop and build measuring equipment; the computing department, a librarian and many other institute staff provide the support that allows the scientists to conduct their research in the first place. Much ado about microbial nothings!? This is the only way that the microbiology of the oceans can be researched. Only in this way can we all learn to understand the world better, piece by piece. And only in this way can scientists maintain their basic research at the highest possible level.

The Max Planck Institute for Marine Microbiology was officially founded July 1, 1992, almost a year after its sister institute, the Max Planck Institute for Terrestrial Microbiology in Marburg. The institute moved into its new premises in the Technology Park at the University of Bremen in 1996; its neighbors today include the Universum Science Center, MARUM – the Center for Marine Environmental Sciences at the University of Bremen, and the Center for Tropical Marine Ecology (ZMT). The MPI, with its three Departments of Biogeochemistry, Microbiology and Molecular Ecology and two Max Planck Research Groups, is one of the world's leading marine research institutes. Since summer 2009 the newly appointed Director Dr. Marcel Kuypers shares responsibility for the Department of Biogeochemistry with Prof. Dr. Bo Barker Jørgensen.

Sediment from the ocean floor holds much in store: a single cubic centimeter of sediment contains around six billion microorganisms – as many as there are human beings on planet earth.

## The Max Planck Institute – Some Facts

| | |
|---|---|
| 1 of 76 | institutes of the Max Planck Society |
| 3 | departments |
| 8 | research groups |
| 2 | Max Planck Research Groups |
| 65 | scientific staff |
| 68 | Ph.D. students |
| 50 | employees providing scientific and technical services |
| 34 | administrative/technical staff |
| 38 | nations |
| 5 bis 6 | to 4 major excursions a year under the leadership of the MPI; |
| ~11 | smaller excursions |
| 6 | frames for automatic deep-sea robots (landers) |
| 13 | measurement systems that can be installed in the equipment frames of the landers, ROV and submarine modules |
| 5972 $m^2$ | of main office and laboratory space |
| 57 | laboratories |
| 1 | thermoconstant room (25°C bis 38°C) |
| 11 | coldrooms (2°C bis 25°C) |
| 1 | deep-freeze room (-18°C) |
| ~200 | peer-reviewed publications a year (papers in journals, books and specialist literature) |
| ~20000 | titles in the library |
| ~80 | currently subscribed journals in the library |
| 13 | patents filed for registration |

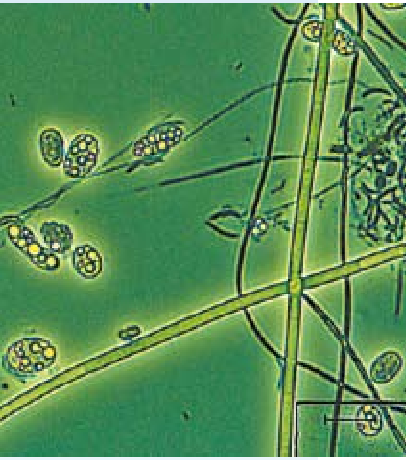
Research vessel Heincke (AWI)

Prof. Dr. Friedrich Widdel, Director and head of the Department of Microbiology

## Department of Microbiology

Microorganisms are the world's natural biodegradation chemists, also in the water. The Department of Microbiology investigates how and under which conditions these biochemical processes take place. It also explores how these reactions sustain the global element cycles of carbon, nitrogen, sulfur and iron. Before researchers can study the metabolic processes in a species of bacterium in detail, they have to isolate this species from others in the sample and grow in a pure culture. To gain insights into the physiological and metabolic function of environmental microorganisms, microbiologists make increasing use of genome analyses, often in collaboration with the Department of Molecular Ecology and the Max Planck Institute for Molecular Genetics in Berlin.

### What are your criteria for the choice of study subjects, and which species and metabolic pathways do you study?



Cyanobacteria: *Chromatium*- and *Desulfonema* species under the microscope

We want to learn more about the microorganisms and the enzymatic reactions underlying environmental processes in aquatic habitats such as sediments. This is why we choose research topics or organisms of global or environmental importance. In doing so, we keep our eyes open for new phenomena.

Fermenters for growing sulphur-oxidising bacteria

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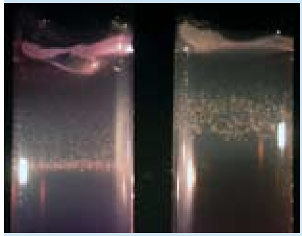
## Ecophysiology Group

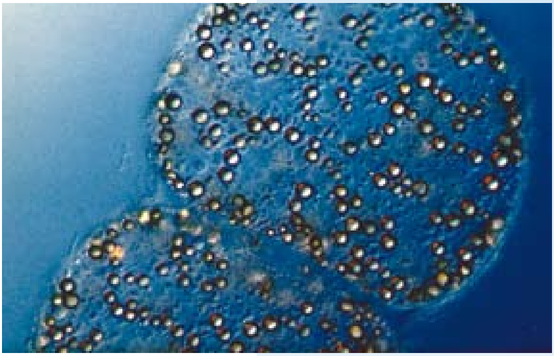
Their motivation is curiosity, their field of research is ecophysiology. Heide Schulz-Vogt and her Ecophysiology Group analyze the influence of sulfur bacteria on different elemental cycles. One important character is *Thiomargarita*, “the sulfur pearl”.

It’s been thirteen years since the bacterium with the nice name was discovered close to the Namibian coast. It is easy to see and it looks like a long, white string of pearls. With its size of 100-300 microns in diameter it is 600 times bigger than Streptococci – the bacteria that cause pneumonia. *Thiomargarita namibiensis* is the biggest known bacterium.



Two different tubes (Ø 1.6 cm) with a culture of *Beggiatoa* filaments: The filaments choose to live at different depths in response to different conditions in the medium.

Because *Thiomargarita* bacteria can’t be cultivated in the lab, the research group also works with close relatives: *Beggiatoa*. They make it possible for the team to find out the relationship between bacteria and the nitrogen cycle on the one hand. On the other hand, they can analyze their impact on the sulfur cycle and the phosphorus cycle.
These cycles proceed all around us every second of every day. They play a crucial role in the balance of nature. The goal is to understand how bacteria influence these processes.



*Thiomargarita namibiensis* as seen in the light microscope: Many sulfur inclusions can be seen within the cells (Ø 0.3 mm).

### What does it take to be a good biologist?

The three most important things you need to be a good biologist are creativity, imagination and the ability to think logically. All of these things combined make it possible to be successful in this profession that is at once highly fascinating and important.

Certain concepts of nature are agreed upon in the scientific community, but only scientific investigation can unveil the truth. Ultimately, it is important to fit your novel observations into a new concept. So the biologist becomes a sort of “private investigator”.

Dr. Heide Schulz-Vogt
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# Department of Biogeochemistry

Prof. Dr. Bo Barker Jørgensen and Dr. Marcel Kuypers, Director and head of the Department of Biogeochemistry

Biogeochemistry: what seems at first sight to be a very esoteric science is actually a useful mixture of disciplines. Useful because only the combination of expertise and data from the fields of biology, geology and chemistry makes it possible to analyze how element cycles are controlled in the sea, what processes occur there, which microorganisms are involved, and how they interact to drive ecological cycles. Thus, scientists in the Department of Biogeochemistry analyze the key element cycles of iron, manganese, nitrogen and sulfur in marine sediments and in the water column. Since summer 2009, Prof. Dr. Bo B. Jørgensen – who founded the new Center for Geomicrobiology at the University of Aarhus in 2007 – has been supported by the new Director, Dr. Marcel Kuypers, head of the Nutrient Group.

## Biogeochemistry Group

Tim Ferdelman, Ph.D.
Head of the Biogeochemistry Group

Marine sediments are the sites of complex turnover of matter. Throughout earth's history the organic remnants of marine life forms have mixed with inorganic debris and precipitates and formed a series of chemically stratified layers. The Biogeochemistry group uses chemical, isotopic and microbial techniques to study the chemical and biological processes in these layers. The main focus is on how the reactants and products associated with the mineralization of organic matter feeds into the global cycles of elements.

### How did you get interested in marine sediments?

As a young student I became fascinated with the chemistry of natural waters, and I soon realized how important the biological and chemical processes in the sea floor are in regulating the composition of the seawater. Acting like a huge filter, this enormous, and reactive, reservoir affects the seawater composition in timescales of tens to millions of years. When we study the chemistry of our sediment cores from ocean drilling projects we have to think in terms of these large geological time and space scales.

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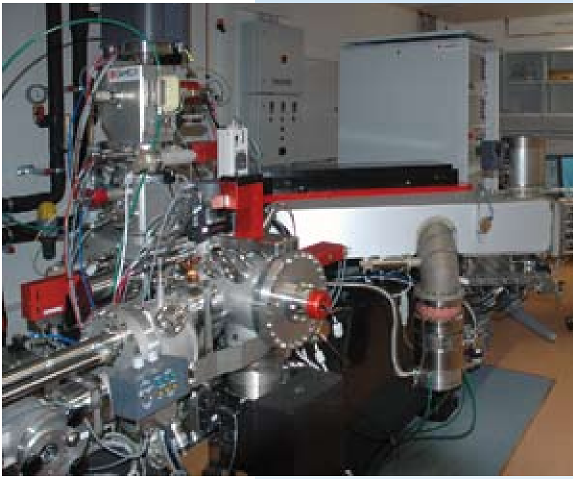
Destillation in the laboratory

# Nutrient Group

The oceanic nitrogen cycle has a leak, namely 'anaerobic ammonium oxidation', or anammox for short. The process was originally discovered in a bioreactor. However, anammox bacteria also occur in nature, as Marcel Kuypers and co-workers have shown for various locations since 2003.
In the Black Sea and oxygen-poor areas of the global ocean, anammox bacteria convert ammonium to gaseous nitrogen, which then rises into the atmosphere. The oceans lose large amounts of nutrients this way, since ammonium acts as a fertilizer for algae. Algae form the basis of the oceanic food web, up to and inclding fish-eating humans, and, as such, anammox is more important than previously thought.
Besides nitrogen, sulfur compounds – poisonous to higher organisms – are also of interest to the scientists. Off the Namibian coast many fish die when hydrogen sulfide rises episodically from the seafloor. During a cruise, Kuypers and his team successfully identified the microorganisms that detoxify the sulfide, thereby alleviating the effects by acting as a biological filter.



NanoSIMS: Secondary ion mass spectroscopy enables insight in the nano scale.

**You and your team are investigating how bacteria and archaea interact with key processes in the nutrient cycle. What is your strategy?**

First of all, we travel out to the ocean and measure the nutrient and oxygen content every half a meter to meter from the surface down to depths of around 400 meters. On board the ship, we determine, among other things, the abundance of microbes in the samples. Back on land, in the laboratory, we further analyze the water samples that we collected on board.
In our investigations, we make use of various disciplines such as biogeochemistry, oceanography, molecular biology, organic geochemistry and others. Using a multiple-method approach we greatly improve our ability to identify new processes.

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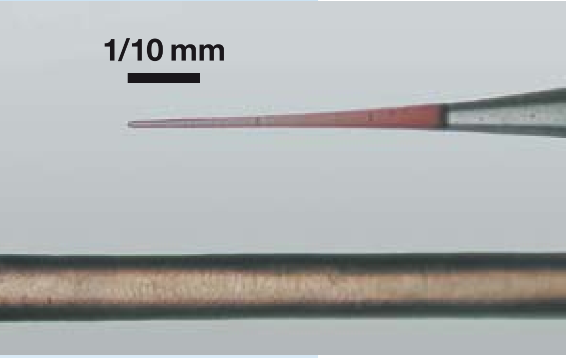
Dr. Marcel Kuypers, Director and head of the Nutrient Group

## Microsensor Group




A microsensor compared to a human hair

A laboratory workshop: here, technicians and engineers build sensors in minute detail. The sensors are just five microns thick – a mere tenth the thickness of a human hair. These electrochemical sensors measure the concentrations of oxygen, hydrogen sulfide, nitrogen compounds or other substances. They operate in the Wadden Sea and in other marine sediments up to 6,000 meters below the water's surface, in biofilms and in microbial mats – every 0.01 to 0.1 millimeters and in situ. Such detailed in situ readings provide microbiologists with data that could not be obtained from samples removed for later analysis in the laboratory. With the help of microsesors, the scientists precisely investigate which substances the microbes convert in which ultrathin layer, how the microbes regulate different element cycles, and thus how they affect the geochemistry. Molecular techniques help to identify the most active bacteria. Dirk de Beer, head of the research group, and the other members of his team often cooperate with the Biogeochemistry and Molecular Ecology Department, and the Microbial Habitat Group.

Dr. Dirk de Beer
Head of the Microsensor Group

**You could buy microsensors from commercial suppliers. Why does your research group design and build its own measuring probes?**

Commercially available microsensors cost about 500 Euros and are not always ideal for our purposes. Our technical staff build the perfect sensors. Moreover, we often need complex equipment like optical sensors, so-called optodes, that are able to measure oxygen distribution in two dimensions simultaneously. In such cases, we work together to develop completely new sensors. The microbiologists in our group say what they want to measure, the physicists and chemists explore the boundaries of what is feasible and then our engineers build the sensor and optimize it. This kind of applied development is the logical way for us to work. It has also resulted in a patent, license agreements and know-how transfer.

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# Mathematical Modeling Group

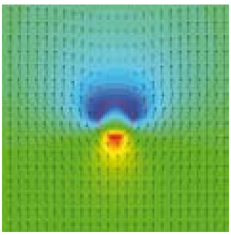
Numerous transport processes in the ocean – in the water column and in the seabeds – are of a combined biological, chemical and physical nature, coupled and driven by hydrodynamics.

Biogeochemical transport – the dynamics of the major biogeochemical cycles in space and time – is based on hydrodynamic coupling. This includes more specific examples such as the impact of the flow rate over permeable sediments on denitrification, the settling of marine snow contributing to carbonate deposits, and the increased permeability in the sediments due to the actions of animals like macrozoobenthos larvae and jellyfishes of the Cassiopeia family.

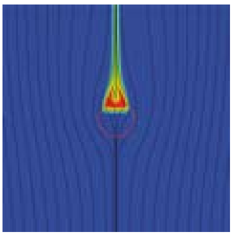
Starting from these topics, the ongoing research in the Mathematical Modeling Group concentrates on the development of numerical models in combination with non-intrusive measurement techniques to study the role of diffusion, advection, and chemical reactions. Furthermore, coupled problems such as particle dynamics, gas transport, motility of microorganisms, and animal motions are addressed, contributing to a more detailed understanding of marine systems in collaboration with the other groups at our institute.

### How can complex physiochemical problems linked to biology be modeled?

The above-mentioned marine processes are complex and involve both the water column and the sediment. Multi-phase reactive flows are modeled by the lattice Boltzmann method (LBM). Based on a recently developed mathematical code, it is now possible to simulate many of these processes with a high level of precision.



Pressure distribution (color map) and the velocity field around/through a porous spherical aggregate



Release of nutrient from a porous aggregate (initially, the sphere had maximum concentration [red])

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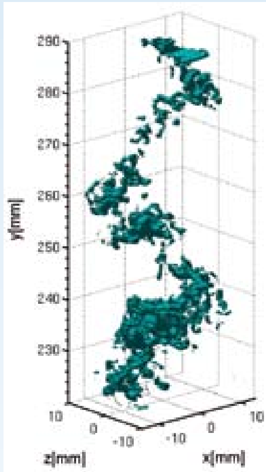
Prof. Dr. Arzhang Khalili
Head of the Mathematical Modeling Group

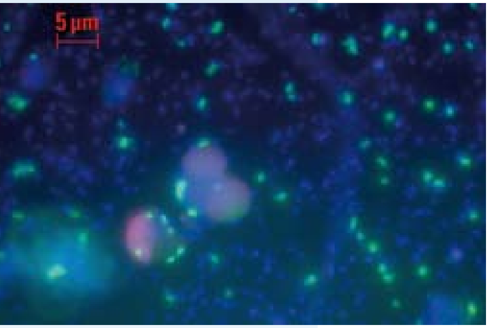



The ecology and biogeochemistry of the ocean are strongly influenced by particle settling, as particles are the main vector of carbon export from the upper ocean toward the ocean floor. Previously, the settling aggregates were considered solid, which, however, leads to an overestimation of the settling velocities, as recently shown by our group.

# Department of Molecular Ecology

Prof. Dr. Rudolf Amann, Managing Director and head of the Department of Molecular Ecology

To protect something, one has to understand it. Scientists estimate that only one in a hundred species is known, especially because most microbes cannot be cultivated and therefore cannot be studied. The Department of Molecular Ecology identifies marine microorganisms on the basis of their nucleic acids with the help of nucleic acid probes. Using additional molecular biological methods, scientists detect specific genes in environmental samples and analyze when, why and in what way bacterial populations behave at a particular location, and for which biogeochemical processes the microbes are responsible. In this way, the staff in the department headed by Rudolf Amann try to unveil which enzymes and microorganisms play a role in the anaerobic oxidation of methane or the aerobic degradation of algal polymers. Moreover, locations with a high level of biodiversity are of special interest, for example the Wadden Sea, where many thousands of different microbe species can be found in a single cubic centimeter.




FISH analysis of a water sample from the North Atlantic near Iceland. Only the part of the organic carbon not mineralized by bacteria is buried in the sediments. Flavobacteria shown here in green prefer the algae *Phaeocystis*.

**Your department discovers, describes and enumerates biodiversity. Do you also develop your own methods for this?**

In most cases, yes. We are always developing innovative techniques, even though one or the other may prove in retrospect to be of no use. ‘Bread and butter technologies’, meaning standard methods such as comparative sequence analysis and fluorescence in situ hybridization, or FISH for short, suffice for initial characterization of species. We then adapt and refine these methods to the specific issues we are examining. Our CARD-FISH method, for example, is much more sensitive – the fluorescent color signal is about ten to a hundred times stronger than in a conventional FISH experiment.

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## Symbiosis Group

Dr. Nicole Dubilier
Head of the Symbiosis Group

Deep down at the bottom of the ocean, far away from the sun's light, unique communities flourish and thrive at hot springs. Like oases in the desert of the deep sea, these hydrothermal vents are densely colonized by animals that live in symbiosis with special bacteria. These symbiotic bacteria do not use the sun to gain energy – instead they produce food for their hosts using geothermal energy from the earth's interior. Nicole Dubilier and her Symbiosis Group study the diversity and evolution of these symbiotic associations. They certainly have enough samples. Over 35 hydrothermal vents have already been found, with many more yet to be discovered. These vents are found worldwide where the earth's plates are spreading apart, causing extremely hot fluids to rise to the seafloor and mix with the surrounding cold deep-sea waters. This is exactly the environment the symbionts need to gain energy for themselves and their hosts.

The deep-sea mussel *Bathymodiolus* dominates the biomass at hydrothermal vents on the Mid-Atlantic Ridge. It has two types of bacterial symbionts that co-occur in the mussel's gills, one of which uses sulfide and the other methane as an energy source. The relative abundance of these two symbionts can vary: at vents with higher sulfide than methane concentrations, mussels have more sulfide- than methane-oxidizing symbionts, at vents with higher methane concentrations it is the other way around.

### Are these symbioses also found in other environments?

The discovery of these symbioses in the deep sea lead scientists to look for them in other environments where reducing chemicals mix with oxidized seawater. We now know that these symbioses occur world-wide in a wide range of animal species in environments as diverse as coral reef sands and sea grass beds, and we are continuously discovering new symbiotic associations. In some symbioses, the bacteria are such efficient food providers that their hosts could afford to reduce their digestive system and no longer have a mouth or gut.

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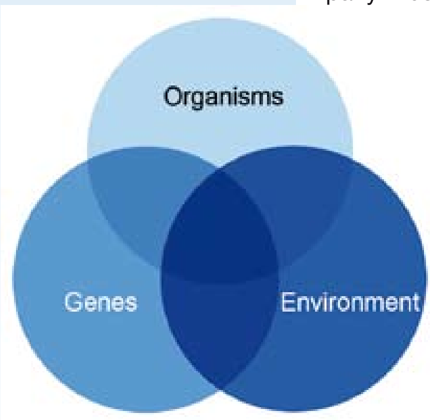
Prof. Dr. Frank Oliver Glöckner
Head of the Microbial Genomics & Bioinformatics Group

## Microbial Genomics & Bioinformatics Group

Over the last decade, great technological and scientific advances have allowed researchers to routinely examine the genome within days. Analyzing the sequence of a genome reveals much of the surprising biological capacities of bacteria. Frank Oliver Glöckner's group investigates how bacteria respond to environmental change. They first analyze genomic sequences with a range of computational techniques in an attempt to understand the 'lifestyle' and ecology of the bacteria under scrutiny.
They determine which components of the genome are active or repressed under specific conditions. Further, the group is developing technologies that integrate analyses of genomic and environmental data to predict how microbes have adapted and will respond to changing environmental conditions. The sheer variety of bacterial lifestyles and capacities is a goldmine for biotechnology. Understanding the consequences and implications of bacterial adaptation and responsiveness to environmental cues allows scientists to better advise politicians and industry leaders in the planning of environmental policy and evaluation of ecological impact. Members of this group also founded the spin-off company Ribocon GmbH in 2005. The company provides know-how and products for sequence and genome analysis to commercial enterprises.




Integration of different parameters – the key to ecosystems biology

**For many decades, biologists have been studying environmentally important bacteria without access to their genetic code. What new insights may be derived from the novel discipline of Ecological Genomics?**

Modern techniques in genomic analysis render a comprehensive understanding of the biological capabilities encoded in bacterial genomes. An analysis of this genomic information integrated with environmental data will provide unprecedented insights into how both organisms and ecosystems function.

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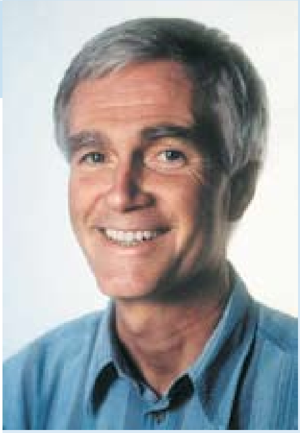
# Center for Geomicrobiology at Aarhus University



Prof. Dr. Bo Barker Jørgensen, Head of the Center for Geomicrobiology and director of the Max Planck Institute

Deeply buried sediments constitute the largest ecosystem on earth in terms of volume and organic carbon pool and they harbor the majority of all prokaryotic organisms (bacteria and archaea) on earth. Yet they constitute the least explored part of the global environment. New developments in analytical and isotope techniques, DNA/RNA-based methods, and drilling and sampling technology have made this fascinating component of planet earth accessible to modern research.

The Center for Geomicrobiology is a joint initiative between the Danish National Research Foundation, the Max Planck Society and Aarhus University. The center addresses key questions concerning microbial life in the energy-starved world deep beneath the sea floor: a) what are the organisms that predominate down there, b) how does their genetic and physiological potential control the biogeochemical processes, and c) how are they adapted to the extremely low energy flux which apparently causes generation times to exceed a thousand years?

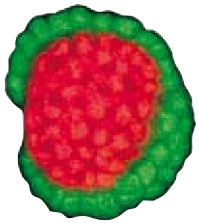
www.biology.au.dk/geomicrobiologydk

The deep biosphere research relies on ships like the research vessel "Joides Resolution". (Photo: www.iodp.org)

# Microbial Habitat and HGF MPG joint Deep-Sea Ecology and Technology Group

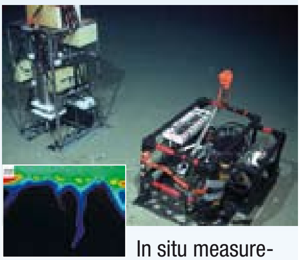
Prof. Dr. Antje Boetius
Head of the Microbial Habitat and HGF MPG joint Deep-Sea Ecology and Technology Group

The seabed comprises an enormous diversity of microbial habitats, which are shaped by biological, geological and physical factors and their spatial and temporal dynamics. How habitat variations influence the composition and function of microbial communities is investigated by 30 co-workers who study deep-sea sediments, gas hydrates, coastal sands, coral reefs and mud volcanoes. Other foci of the research group are the monitoring of oxygen depletion and its consequences for aquatic systems (www.hypox.net), and the investigation of marine sources and sinks for the climate gas methane. In 1999, the group-leader Antje Boetius discovered methane-consuming archaea in deep-sea sediments, which have an important function as biological filter against methane emission. The study of methane-consuming microbes is a central theme of the MPI. Together with international cooperation partners, the institute maintains a deep-sea mud volcano observatory to investigate the interaction between temperature, microbial activity and gas emission.



A symbiosis of methane-consuming archaea (red) and sulfate-reducing bacteria (green)

Sampling of bacterial mats at an Arctic mud volcano



In situ measurements of benthic fluxes in the deep sea

### New goals for deep-sea research

The HGF MPG joint Deep-Sea Ecology and Technology Group was founded with the Alfred Wegener Institute for Polar and Marine Research (AWI) to enable a new focus on Arctic deep-sea ecosystems. The Arctic Ocean changes rapidly due to ocean warming and the retreat of sea ice. The new group investigates the influence of these changes on the deep Arctic, by studying the diversity of polar deep-sea sediments, by measuring biogeochemical processes with deep-sea robots and freefalling "landers" at AWI's long-term observatory "Hausgarten" and in the central Arctic.

aboetius@mpi-bremen.de · www.mpi-bremen.de/en/Habitat_group.html

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# Max Planck Research Group for Microbial Fitness

Microorganisms are our planet's greatest chemists. Almost every chemical reaction that is thermodynamically feasible is exploited by these organisms to sustain survival. Together, the actions of microbes comprise the biogeochemical element cycles, a vastly complicated metabolic network that is the basis of all life. It is currently estimated that there are approximately $10^{30}$ of these "great chemists" on planet earth. The number of stars in our universe appears rather low in comparison, at $10^{23}$.
But what are the selection criteria for microorganisms? Which environmental conditions determine whether microorganisms succeed in evolution or not? These are the research questions of the Microbial Fitness Group headed by Marc Strous.

The experimental design to address these questions starts with the sampling of microbial communities in the natural environment. The obtained samples are incubated in laboratory bioreactors under different environmental conditions to stimulate natural selection, as Charles Darwin would say. Using highly sensitive temperature measurements the scientists can track the thermodynamic efficiencies of the competing microorganisms. Metagenomic analyses reflect the total genetic information of the microorganisms. With bioinformatic methods like metagenome analyses it is now possible to reconstruct parts of genomes or even complete genomes of single microorganisms.

### What was your initial idea to combine metagenomics with highly sensitive temperature measurements?

Metagenomics is a most successful, modern technique, and combining it with highly sensitive temperature measurements is a pioneering effort. Recent technical progress creates the possibility of high-resolution temperature measurements. The lower the temperature production of a microbial community, the higher its productivity. "Imagine you ignite 1,000,000 candles," says Marc Strous. "You'll notice the change in temperature when one of the candles goes out."

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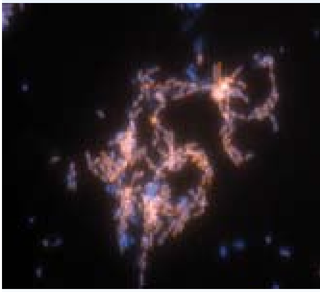
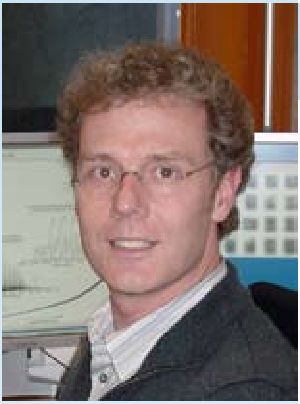
Prof. Dr. Marc Strous
Head of the Max Planck Research Group for Microbial Fitness

Set-up for measuring nitrogen, oxygen, methane and other nitrogen species



*Methylomirabilis oxyfera*, a recently discovered methane oxidizer



Dr. Thorsten Dittmar
Head of the Max Planck Research Group for Marine Geochemistry

# Max Planck Research Group for Marine Geochemistry

The Max Planck Research Group for Marine Geochemistry at the Institute for Chemistry and Biology of the Marine Environment (ICBM, University of Oldenburg) studies dissolved organic matter (DOM) in the ocean. The ocean is one of the largest carbon reservoirs on earth. Dissolved organic matter alone contains a similar amount of carbon as all living biomass in the ocean and on land combined. Even though marine dissolved organic matter is mainly of microbial origin, its turnover in the ocean is remarkably slow. Dissolved organic matter has accumulated in the ocean over thousands of years, and the controlling mechanisms behind its turnover and cycling are largely unknown. Advanced molecular techniques, in particular ultrahigh-resolution mass spectrometry, are used in the research group to obtain answers to the fundamental questions regarding the cycling of organic matter in the oceans.

### Why do you need ultrahigh-resolution mass spectrometry for your research?

It is the most powerful technique to molecularly characterize complex organic mixtures, such as DOM, petroleum or humic substances, whose composition is still largely unknown. We can determine the mass of an individual molecule with a precision of one ten-thousandth of a Dalton, which is less than the mass of an electron. This level of precision is required to identify individual molecules in seawater. There are only five of these powerful mass spectrometers in the entire world.

Sea ice in the arctic Weddell Sea. More than 1,000 meters of water lies below the scientists and the emperor penguins. At this station dissolved organic material was sampled in and under the ice.

### Your research group is located in Oldenburg. How is the cooperation with the ICBM?

This location is ideal for us, mainly because of the geochemical expertise at the ICBM. We have established excellent cooperation with the geochemistry and microbiology groups of the ICBM. Via the intranet, we are in a permanent contact with the Max Planck Institute and it is just an hour's drive away.

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Dittmar T., J. Paeng. 2009. A heat-induced molecular signature in marine dissolved organic matter. Nat. Geosci. 2: 175-179.

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# Spin-off: Ribocon GmbH

## Cutting-Edge Bioinformatics for Industry and Science

Max Planck Institutes encounter unexplored fields and generate a number of innovative methods and solutions during their research. This know-how is of major interest and leads to successful cooperation between science and industry. Scientists from the Microbial Genomics Group founded the company “Ribocon” together with the group leader, Prof. Dr. Frank Oliver Glöckner, and an external expert for finances, in 2005.

Ribocon focuses on the analysis of genetic information (DNA sequences) in microbiology. This field, designated as bioinformatics, ranges from the utilization of selected marker genes to the investigation of complete genomes (the full genetic information of an organism) and is gaining importance at tremendous speed. While just a few years ago, the Human Genome Project was started as a long-term venture, today an immense amount of genetic data can be produced highly cost efficiently in a very short time. However, the raw data provided by the DNA sequencing facilities represent merely the starting point on the path to biological knowledge.

The flood of DNA data that comes with modern technologies represents a tremendous challenge for the users of this young but highly relevant field. To analyze the data, expert knowledge and powerful computer systems are required. At this point, Ribocon offers professional services and support into which the Ribocon team members bring experience from their previous work at the MPI: in 2002 they were the first to analyze the genome of a bacterium isolated from an environmental sample.

Ribocon GmbH is continuously developing solutions for DNA sequence analysis and offers corresponding services and products. The customers originate in equal parts from basic research, (routine) diagnostics, and the wide discipline of biotechnology. In addition, the Ribocon team is involved in scientific projects relating to applied research or requiring extensive knowledge transfer.

Training and education by Ribocon staff

Contact: Dr. Jörg Peplies · jpeplies@ribocon.com · www.ribocon.com

### What is fascinating about your science?

I am interested in the role of coastal sediments in the ocean carbon budget and in the response of ocean chemistry to anthropogenic carbon emissions. I think the main obstacle to a better understanding of coastal processes in global models is the overwhelming complexity of coastal ecosystems. Recent discussions have sparked cross-disciplinary, international research initiatives aimed at advancing our understanding of coastal ocean processes, and I am excited to contribute.

Alexandra Rao, Ph.D., Scientist, Microsensor Group

I am fascinated by the basic mechanisms by which microorganisms degrade long-chain hydrocarbons like paraffin wax or diesel oil. A lot of oxygen-breathing bacteria can break the hydrocarbon chains using oxygen molecules as "leverage". This is a priceless contribution to the decontamination of water bodies. Such degradation processes also happen under oxygen-free conditions and are highly valued, for instance in wastewater treatment plants. But what kind of "leverage" might the bacteria use if no free oxygen were available? Alongside the recently discovered "fumarate addition", an unknown novel mechanism exists. But how does it operate? At the Max Planck Institute I am working together with a lot of dedicated experts on these intriguing topics.

Johannes Zedelius, Ph.D. student, Department of Microbiology

Measuring of sulfate reduction in the laboratory

One million bacteria live in one milliliter of seawater. However, we do not always know what they live on, since their food – dissolved organic matter – is rather scarce in the open ocean. I am fascinated by these frugal (oligotrophic) bacteria and how they can survive and even multiply under those extremely limited conditions. In my studies I combine traditional cultivation methods with modern techniques like genome sequencing.

Anne Bachmann, Ph.D. student, Ecophysiology Group

What could fascinate grown men about digging in mud, and often smelly mud, at that? What most people don't know is that the microbes that inhabit the smelly mud hold the key to our understanding of the earth's ecosystem. By "inventing" carbon dioxide fixation, the early ancestors of these microbes provided the food resources for herbivores and carnivores and by exhaling oxygen they made the evolution of large and complex organisms possible. They recycle nutrients like phosphorus and nitrogen and render ecosystems sustainable. The environmental microbes are the basis and the drivers of life on earth. This fascinates me and understanding their role and the mechanisms by which they fulfill that role is what drives my interest. The Max Planck Institute for Marine Microbiology is one of the leading institutions in the world for studying these interesting organisms. That is why I chose it as host institute for my one-year sabbatical.

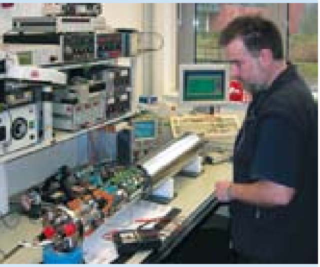
Sampling in the Wadden Sea

Prof. Dr. Kai Finster, Guest Scientist, Department of Molecular Ecology

Together with my colleagues from the Max Planck Institute and external cooperation partners all around Europe I am dealing with low-oxygen habitats of the ocean. Most life in the ocean depends on oxygen. However, due to global warming and increasing anthropogenic pollution of the oceans, oxygen consumption is increasing rapidly. More and more aquatic habitats are being more and more heavily affected. Even now, mussels, crabs and fishes cannot survive in some habitats. This science is really dear to our hearts. Learning more about the processes responsible will enable us to better protect the affected environments.

Dr. Anna Lichtschlag, Scientist, Microbial Habitat and HGF MPG joint Deep-Sea Research and Technology Group

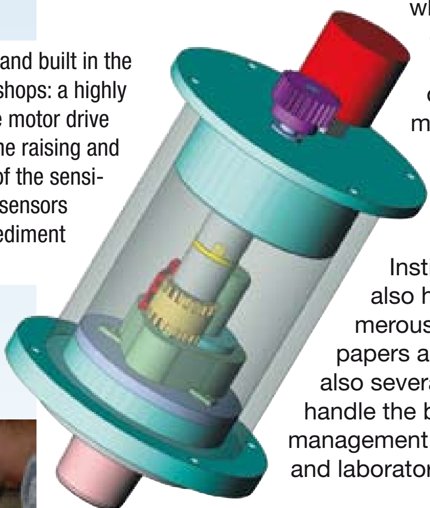
## No Science without Support Staff



The sensitive measurement electronics are encased for protection inside a robust high-pressure cylinder.

Commercially available measuring apparatus and equipment is of little help when it comes to novel experimentation methods and unusual research locations. What can be bought is modified; what cannot be bought is designed and built – in the institute's own, well equipped workshops for electronics and mechanics. Both have their separate staff and facilities, but they work together. The mechanics workshop, for example, constructs precision equipment and other millimeter-scale components; the electronics workshop adds the electronics. The electronics workshops alone has developed almost 200 technical modules since the institute was founded, including various kinds of electronic control systems and a new kind of measurement technology using optical instead of chemical sensors.

To pursue their research, scientists are reliant not only on the workshops, but also on other support staff, for example the computer specialists in the computing department, and the three staff members responsible for building services engineering, who perform daily maintenance on the ventilation, cooling, fire alarm, access control and other technical systems, remedy or repair minor faults themselves, and call in specialized firms to deal with major problems and complex projects. The Max Planck Institute for Marine Microbiology also has an excellent library with numerous books, journals, daily newspapers and its own librarian. There are also several administrative staff who handle the bookkeeping, human resources management and the procurement of office and laboratory equipment.



Designed and built in the MPI workshops: a highly adjustable motor drive controls the raising and lowering of the sensitive microsensors into the sediment layer.

To ensure that the scientific staff do not just publish in specialist magazines and journals and deliver presentations at conferences, the press department informs the general public about the research being conducted and the main findings obtained – by issuing press statements, conducting guided tours of the institute, publishing information material and organizing various campaigns, for example on the annual Girls' Day or other nationwide initiatives.

The technical staff in the laboratories are needed in a variety of areas.

# Teaching and Studying

The Max Planck Institute for Marine Microbiology is not only a center for research, but also for teaching and studying.
Today's marine scientists educate tomorrow's in many different ways. For example, some of the scientists at the Max Planck Institute are lecturers at the University of Bremen (Departments of Biology and Geosciences), at the Jacobs University in Bremen (Department of Bioinformatics & Computational Biology) and at other institutes of higher education.

Starting microbial cultures, taking samples and performing analyses are just some of the many daily tasks for prospective marine biologists.

## International Max Planck Research School of Marine Microbiology – MarMic

The joint M.Sc. and Ph.D. program of the International Max Planck Research School of Marine Microbiology, MarMic, founded in 2002, is synonymous with excellence in graduate advancement: young, highly talented scientists study with scientists of international repute at the Max Planck Institute for Marine Microbiology, the Alfred Wegener Institute for Polar and Marine Research, the University of Bremen and the Jacobs University.
Each year, as many as twelve selected students embark on a twelve-month training course comprised of lectures, tutorials and internships. They then write their Master's thesis and enter the three-year doctorate phase. Once they have completed their Ph.D., MarMic graduates become a new generation of marine scientists. Having received interdisciplinary training, they go on to conduct research into microbial life and its impacts on the biosphere.

www.marmic.mpg.de

Taking samples on the island of Sylt: MarMic students show great zeal.

## International Studies in Aquatic Tropical Ecology – ISATEC

It's all in the name! Anyone taking the two-year M.Sc. degree course entitled International Studies in Aquatic Tropical Ecology (ISATEC) spends one term researching at an institute in Brazil, Costa Rica, Indonesia or another tropical country. Before they leave, the students in a particular year, up to 22 in number, must attend lectures and complete their first practicals. The degree is offered by the University of Bremen in cooperation with the Center for Marine Tropical Ecology (ZMT). Scientists at the Max Planck Institute for Marine Microbiology also give lectures and lead some of the practicals for the ISATEC students.

www.isatec.uni-bremen.de

Layer for layer, prospective marine biologists remove cores for further analysis.

Production and inspection of microsensors under the microscope

### The MPI as a Training Center for Chemical Laboratory Technicians

For some years now, the Max Planck Institute in Bremen has been training high school graduates as chemical laboratory technicians. After basic practical training lasting two to three months, held at the facilities of cooperation partner, the University of Bremen, the trainees pass through various different research groups within the institute. Like the chemical laboratory technicians on the staff, they mainly work in the lab, where their tasks include weighing out samples, cleaning substances, conducting routine experiments, and organizing workflows.
Throughout their training, which lasts three-and-a-half years in total, the prospective laboratory technicians spend two days a week at the SII Utbremen Education Center, where they are taught chemistry, equipment technology, laboratory safety and other subjects. The MPI recruits one trainee a year.

www.chemie.uni-bremen.de/azubis/Laborantenseite.htm

## Cooperation Partners

AWI
Stiftung Alfred-Wegener-Institut
für Polar- und Meeresforschung
in der Helmholtz-Gemeinschaft
www.awi-bremerhaven.de

Haus der Wissenschaft
www.hausderwissenschaft.de

JACOBS UNIVERSITY
www.jacobs-university.de

CARL VON OSSIETZKY universität OLDENBURG
www.uni-oldenburg.de

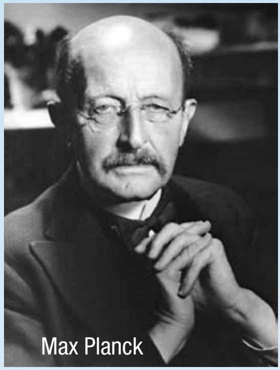
Universität Bremen
www.uni-bremen.de

# The Max Planck Society

The Max Planck Society for the Advancement of Science is a research organization rich in traditions yet also at the cutting edge of research. For decades, using methods and equipment that are continuously being improved and advanced, the society explores what 'holds the world together in its innermost being' (J. W. Goethe). This basic research also establishes the basis for novel therapies and technologies. 'Insight must precede application' is a basic principle of the society and was coined by Max Planck (1858-1947), the physicist and Nobel laureate after whom the society is named.

A co-founder of quantum theory, Planck channeled all his efforts into basic research and fought for the freedom of science – as the Max Planck Society continues to do to this day.
The current president, Prof. Peter Gruss, once wrote: 'The point is to network research worldwide, without surrendering the diversity that exists. The scientific community must preserve its freedom to choose its own topics and set its own goals.'
This is also a clear expression of the organization's mission: to complement the work done at universities and other research establishments with its range of life sciences, natural sciences and humanities, and to make knowledge freely accessible.
There are 76 Max Planck Institutes in Germany, organized into three main sections: the Biology and Medicine Section, the Chemistry, Physics and Technology Section, and the Humanities Section.
There are three additional research institutes and several subsidiary offices in other countries. The Max Planck Society employs 13,000 people in total, of whom one in three is a scientist. They are joined by more than 7,000 students and guest scientists who study and research at the institutes. Conversely, scientists from the Max Planck Institutes are invited as guests to other research establishments all over the world.

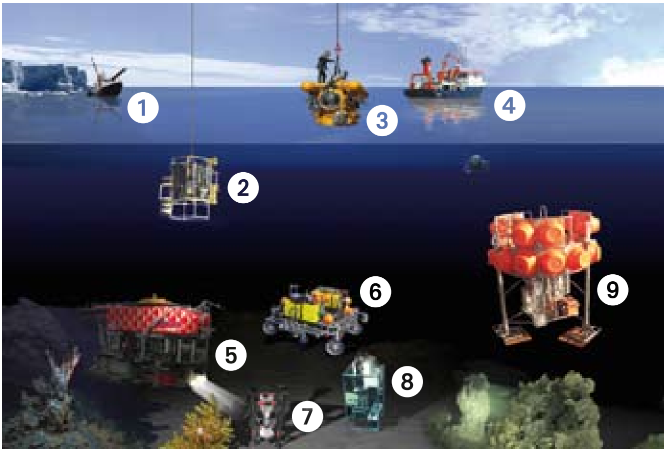
The Max Planck Society enjoys an excellent reputation at both national and international levels, not least because it has produced 17 Nobel laureates to date – two more than its predecessor, the Kaiser-Wilhelm-Gesellschaft, established in 1911. The latter was much respected worldwide, but after the Second World War it was imperative that a fresh start also be made in German science and research. To this end, the Max Planck Society for the Advancement of Science was founded on February 26, 1948. Although it was mainly financed with public funding from the federal and state governments, it is not a state institution, but a non-profit and independent organization.


Max Planck

## Nobel laureates from the Max Planck Society

| | |
|---|---|
| 2007 | Gerhard Ertl (Chemistry) |
| 2005 | Theodor W. Hänsch (Physics) |
| 1995 | Paul J. Crutzen (Chemistry) |
| 1995 | Christiane Nüsslein-Volhard (Medicine) |
| 1991 | Erwin Neher (Medizin) |
| 1991 | Bert Sakmann (Medicine) |
| 1988 | Johann Deisenhofer (Chemistry) |
| 1988 | Robert Huber (Chemistry) |
| 1988 | Hartmut Michel (Chemistry) |
| 1986 | Ernst Ruska (Physics) |
| 1985 | Klaus von Klitzing (Physics) |
| 1984 | Georges Köhler (Medicine) |
| 1973 | Konrad Lorenz (Medicine) |
| 1967 | Manfred Eigen (Chemistry) |
| 1964 | Feodor Lynen (Medicine) |
| 1963 | Karl Ziegler (Chemistry) |
| 1954 | Walther Bothe (Physics) |

**Max Planck Institute for Marine Microbiology**




1 RV Polarstern
2 CTD Watersampler
3 Submarine Jago
4 RV Heincke
5 ROV Quest 4000
6 CMOVE underwater vehicle
7 Gas bubble catcher
8 Profiler with micro-sensors
9 Freefalling lander


Dangerous goods container

Submarine Jago ▶

Waterproof electronic device

Isotopic laboratory

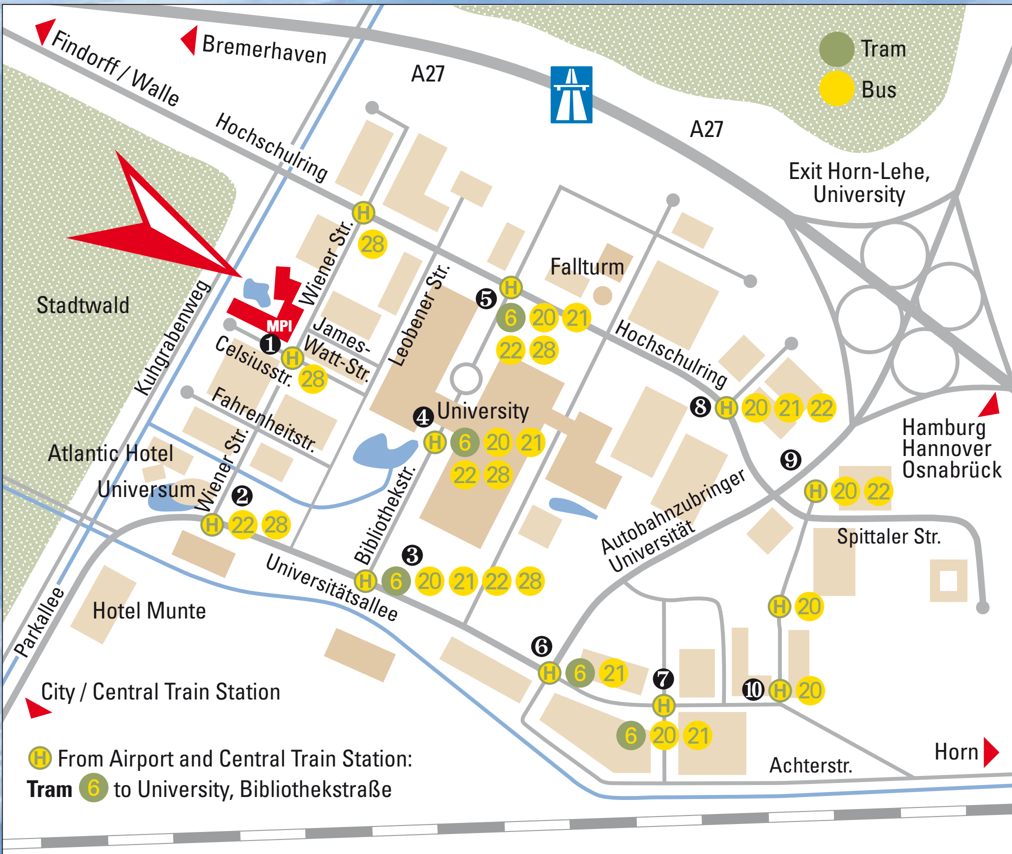
Pipetting robot

Sulfur bacteria *Beggiatoa*

Young student at the microscope

Max Planck lecture hall

## How to get to us:




**Bus- and tram stops**

1. Celsiusstraße
2. Wiener Straße
3. University / NW1
4. University / Zentralbereich
5. University / Klagenfurter Str.
6. Lise-Meitner-Straße
7. Berufsbildungswerk
8. Linzer Straße
9. Spittaler Straße
10. Kremser Straße

# Max Planck Institute for Marine Microbiology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