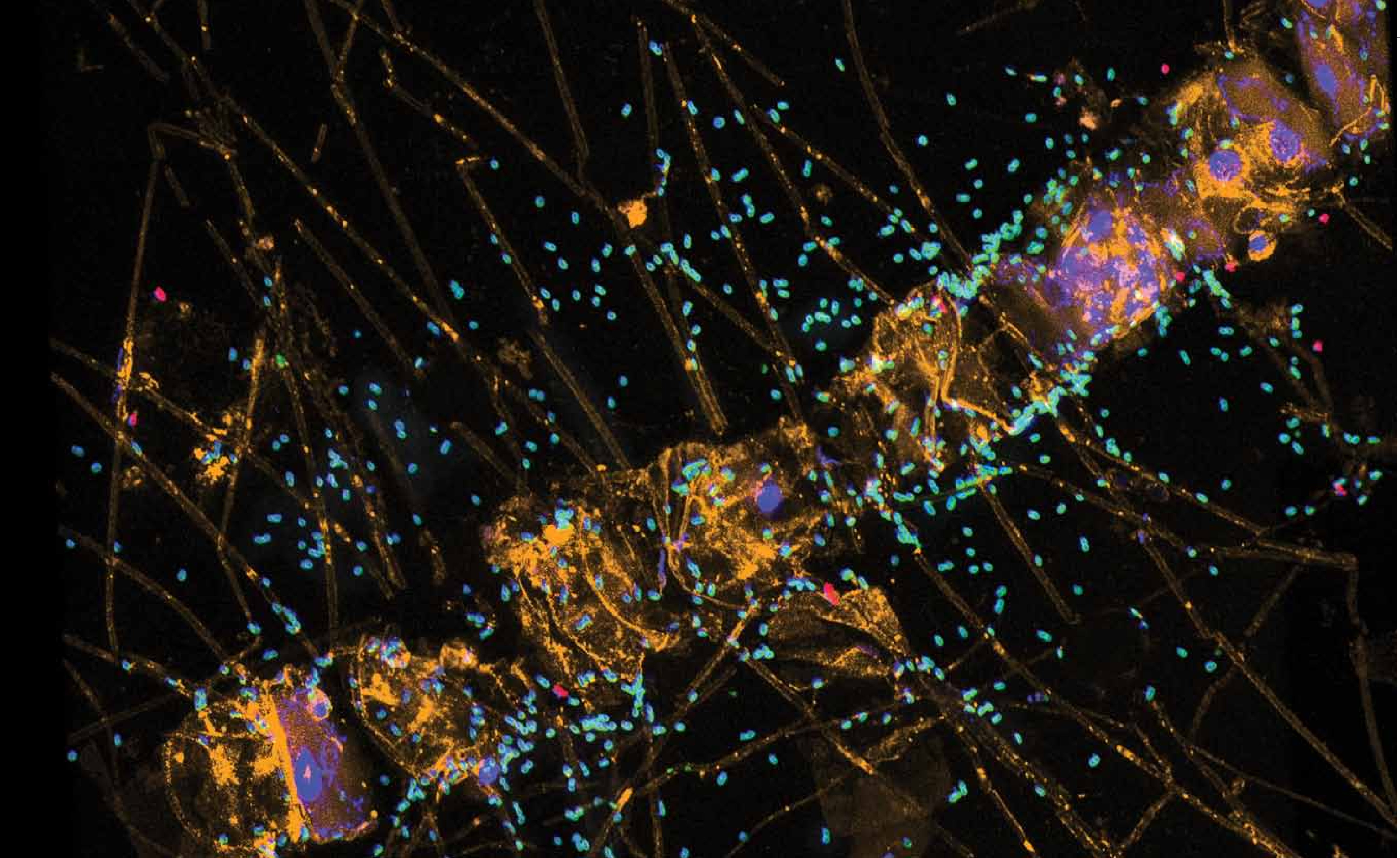
MAX PLANCK INSTITUTE FOR MARINE MICRO BIOLOGY

“No water, no life.
No blue, no green.”

Sylvia Earle, marine biologist



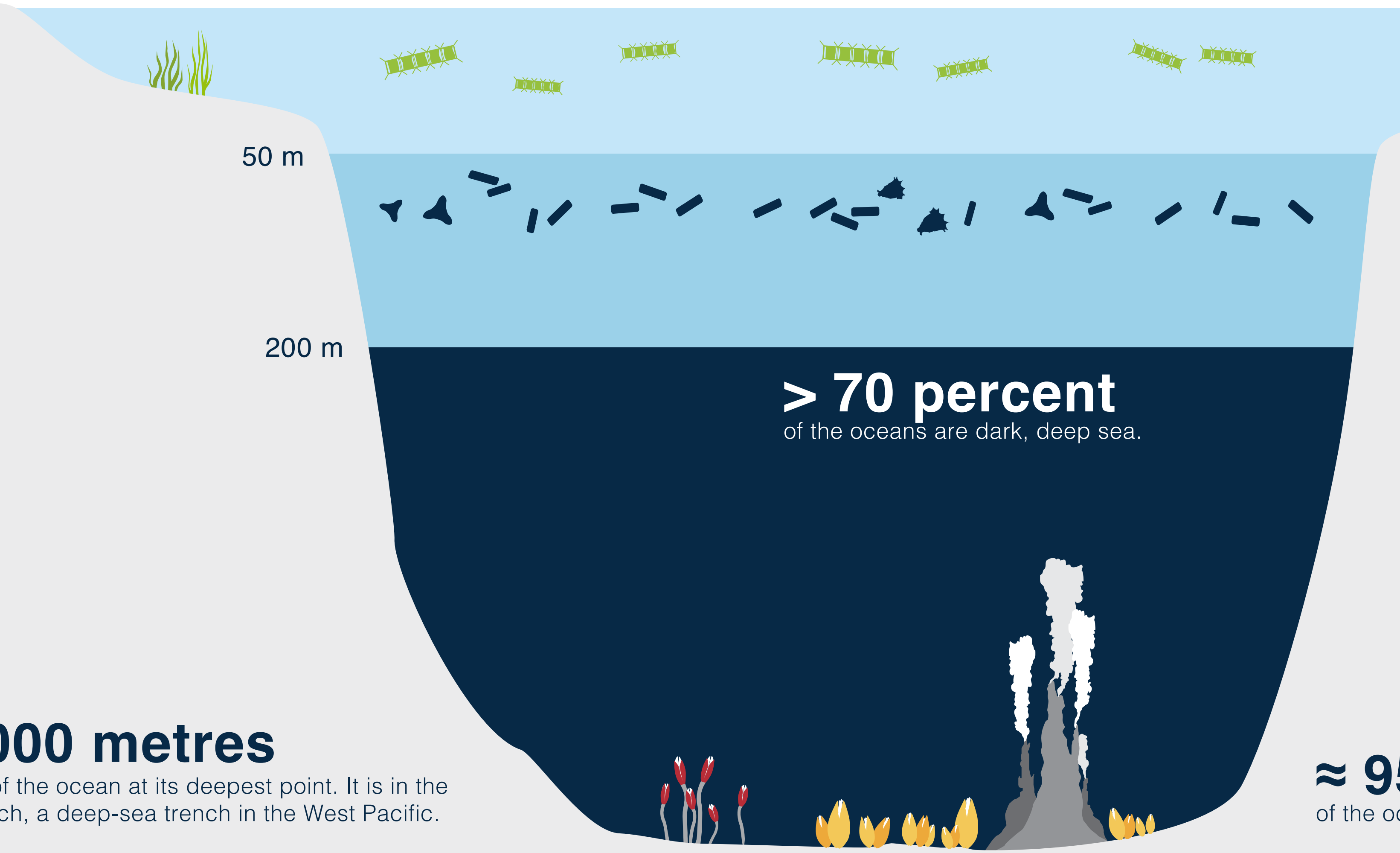
What we study

Microorganisms are small, but have a huge impact: Bacteria, viruses and other microbes have reshaped our planet throughout its history. Blue algae, for example, also known as cyanobacteria, caused the release of free oxygen by photosynthesis in Earth's early history. Only then did it become possible for oxygen-breathing organisms to evolve. And that's only one example: Microbes have a major impact on global element cycles – in the air, in the soil and in the oceans. As marine microbiologists, we study tiny organisms in the oceans, both in the water and beneath the seabed. Even the microbes living many kilometres under the seafloor, of which there are still numerous, little-known life forms, can affect the biochemistry our oceans. We aim to understand how the marine cosmos of minuteness functions and what drives it.

300-times
more habitat is available in the oceans compared to land.

Cosmos of minuteness
Microbiology focuses on microorganisms and their interactions with the environment. Who's who and what does a specific species do?
To find the answers to these questions, we analyze the microbes down to their smallest components – and continuously uncover amazing and fascinating results.

2/3
of the planet is covered by water.



> 10.000
bacteria, covering more than a thousand species, exist on a single sand grain.

≈ 1 billion
microbes live in a single litre of seawater.

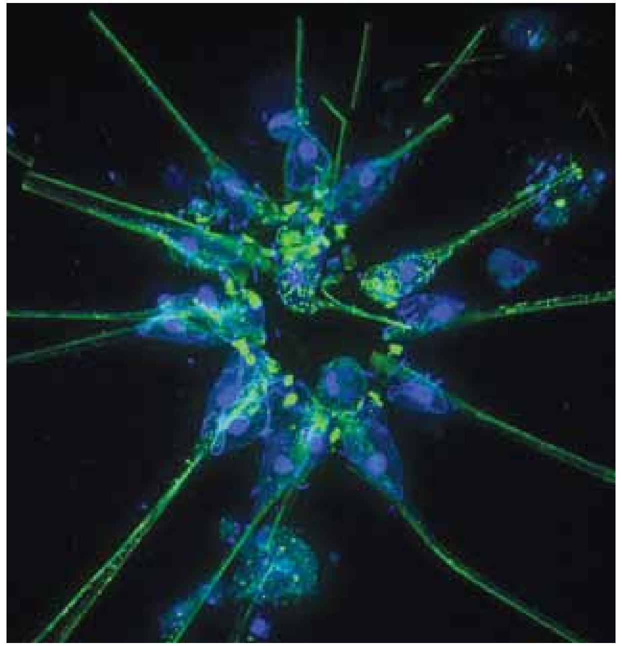
Small, but mighty
Microorganisms are small, but have a profound influence on all aspects of our planet and its inhabitants. Single-cell organisms, many of which cannot even be seen without a microscope, significantly influence life on this planet. In molecular ecology, we explore the diversity and function of these tiny puppet masters in Germany's coastal Wadden Sea and in the open ocean, near the light-flooded surface and in the jet-black deep sea.

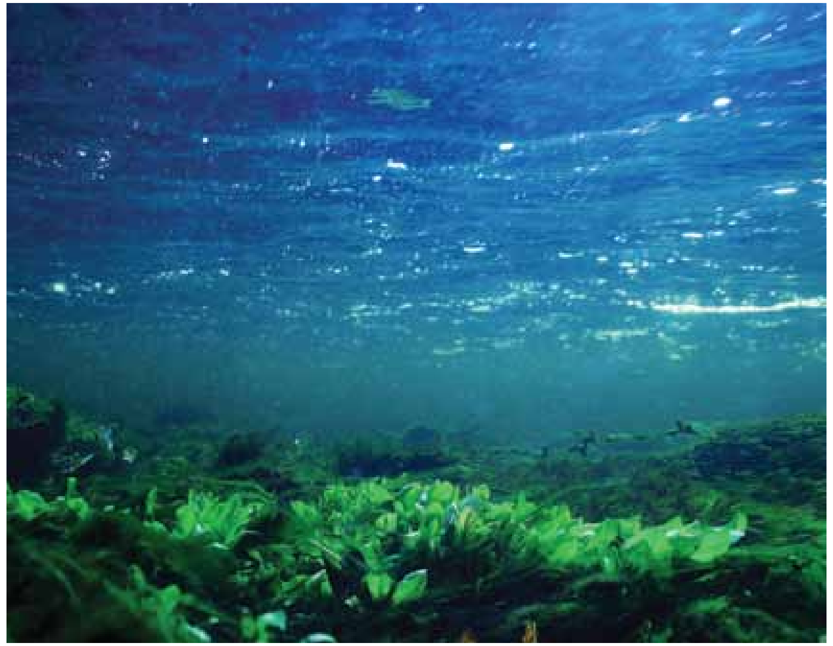
≈ 365,000 kilometres
is the length of coastline around the globe. This figure includes the coastlines of all continents and the majority of islands. Numerous small islands are not included – but even so, this is as long as nine times around the equator or as far away as the moon!

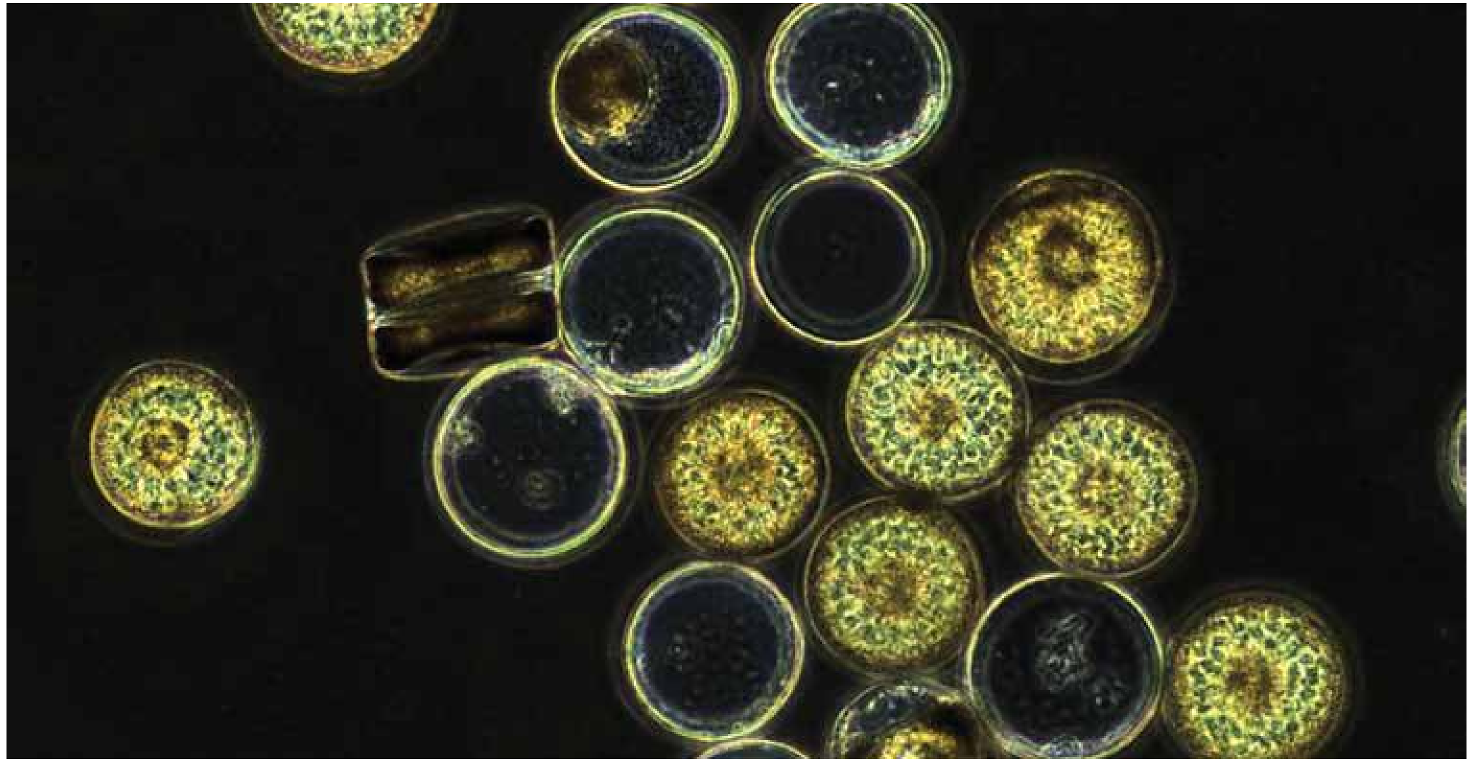
> 70 percent
of the oceans are dark, deep sea.

≈ 11,000 metres
is the depth of the ocean at its deepest point. It is in the Mariana Trench, a deep-sea trench in the West Pacific.

≈ 95 percent
of the oceans remain unexplored.



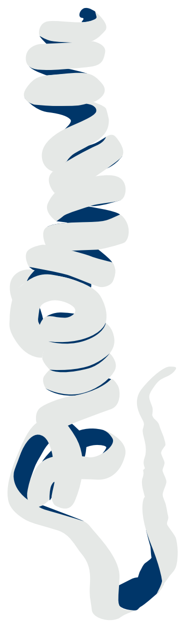


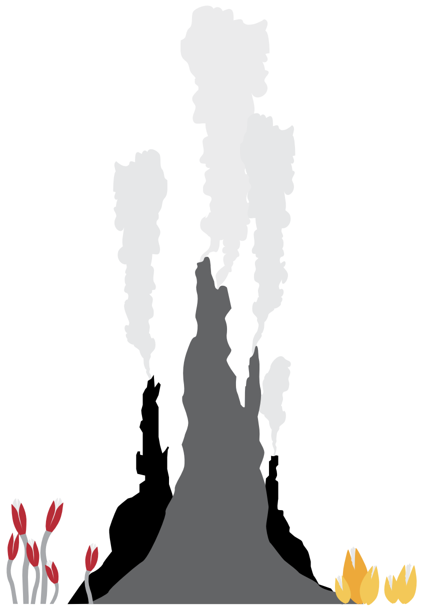


The clean-up crew is coming – the same bacteria clean up time after time
The days are getting longer, the temperatures are climbing, everything is turning green – including in the oceans: Every spring, tiny algae grow in the North Sea, an algal bloom begins. The algae bind carbon dioxide from the air by photosynthesis. After a while, they die and bacteria decompose their remains. Some of the absorbed carbon dioxide is released again. But how much exactly? To find this out, we first need to understand how the bacterial clean-up team works. While different algal species dominate the bloom each year, the same microscopic clean-up crew do duty again and again. Apparently, it is not the algal species that determines which bacteria preferentially multiply, but rather their ingredients, especially their so-called polysaccharides. If different algae contain the same or similar sugars, they can be broken down by the same bacterial enzymes.

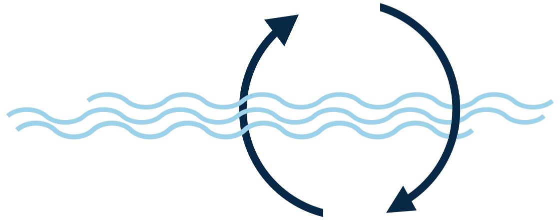
Difficult to digest or elixir of life?
Crude oil, methane or hydrogen sulphide: These substances are anything but compatible to most lifeforms – but they are elixirs of life for some microbial specialists. Some bacteria, for example, can degrade petroleum with oxygen; that is, they feed on it. Others convert methane into carbon dioxide with the help of iron. As a result, further substances are released that can be exploited by other organisms. We explore the microbiological and chemical principles behind these processes: Which microbes do what, which are particularly efficient at it? What do they need to grow particularly well and can we promote their growth? It would then be possible to stimulate nature to clean itself, for example after an oil spill or sewage pollution.

The “we” wins
Collaboration for the benefit of all concerned: Sounds good, and it is. Such symbioses also exist between bacteria and animals. Together, they manage to populate even the most extreme habitats. For example, the deep sea – pitch black, icy cold and low in nutrients. The secret is called chemosynthesis: Bacteria use energy from the seafloor, for example, methane or hydrogen sulphide, for fixing carbon dioxide into sugars and other biomass with which they feed their symbiotic partners, e.g. worms and mussels.





Quid pro quo – not without my partner
At hydrothermal deep-sea vents, where hot, mineral-rich water flows from the seafloor, symbioses are everywhere. Photosynthesis is not possible here, because no sunlight can penetrate this deep. Instead of light, the microorganisms here use chemical energy, such as sulphide or methane, to fix carbon dioxide into biomass. In fact, quite a lot of biomass: Some tubeworms here grow to several metres in length – without ever eating even a single bite themselves. Instead, bacteria inside the tubeworms use sulphide from the vent water as an energy source to fix carbon dioxide into biomass, and the tubeworms live off the bacteria. Bacteria enter into similar “life agreements” with mussels, snails and small shrimp – but definitely not unselfishly: The bacteria live within their hosts in comfortable security and are always close to their nutrient source. Quid pro quo.



Here, the chemistry is good
Always something different, always something new: Life is in a state of constant change. We research the cycles of a variety of substances in the oceans, for example carbon and nitrogen. From the surface to beneath the seafloor. For this purpose, we focus on the individual cell at small scales, and on the entire ecosystem on a large scale. We examine who or what controls the processes involved, how they influence each other and what this means for the oceans today and in the future.

Cycle with a leak
Carbon controls the climate, nitrogen controls plentifulness: The nutrient nitrogen dictates how fast and profusely plants grow. In the oceans, nitrogen upwells from the deep sea to surface waters, where algal growth booms as a result. But freshwater from rivers, too, provides nitrogen compounds to the oceans. These are leached from agricultural fields – the more they are fertilized, the greater the input. This presents a risk, because this oversupply of nitrogen could turn the sea anoxic. Luckily, there are marine microbes that ensure a healthy chemical balance: So-called anammox bacteria, which break down nitrogen compounds. This releases nitrogen gas that escapes into the atmosphere. The oceanic food chain thus once again loses a good part of this growth-stimulating nutrient. This alters its global balance and, consequently, also that of carbon. The anammox leak must therefore be incorporated in long-term climate assessments.

Where we study

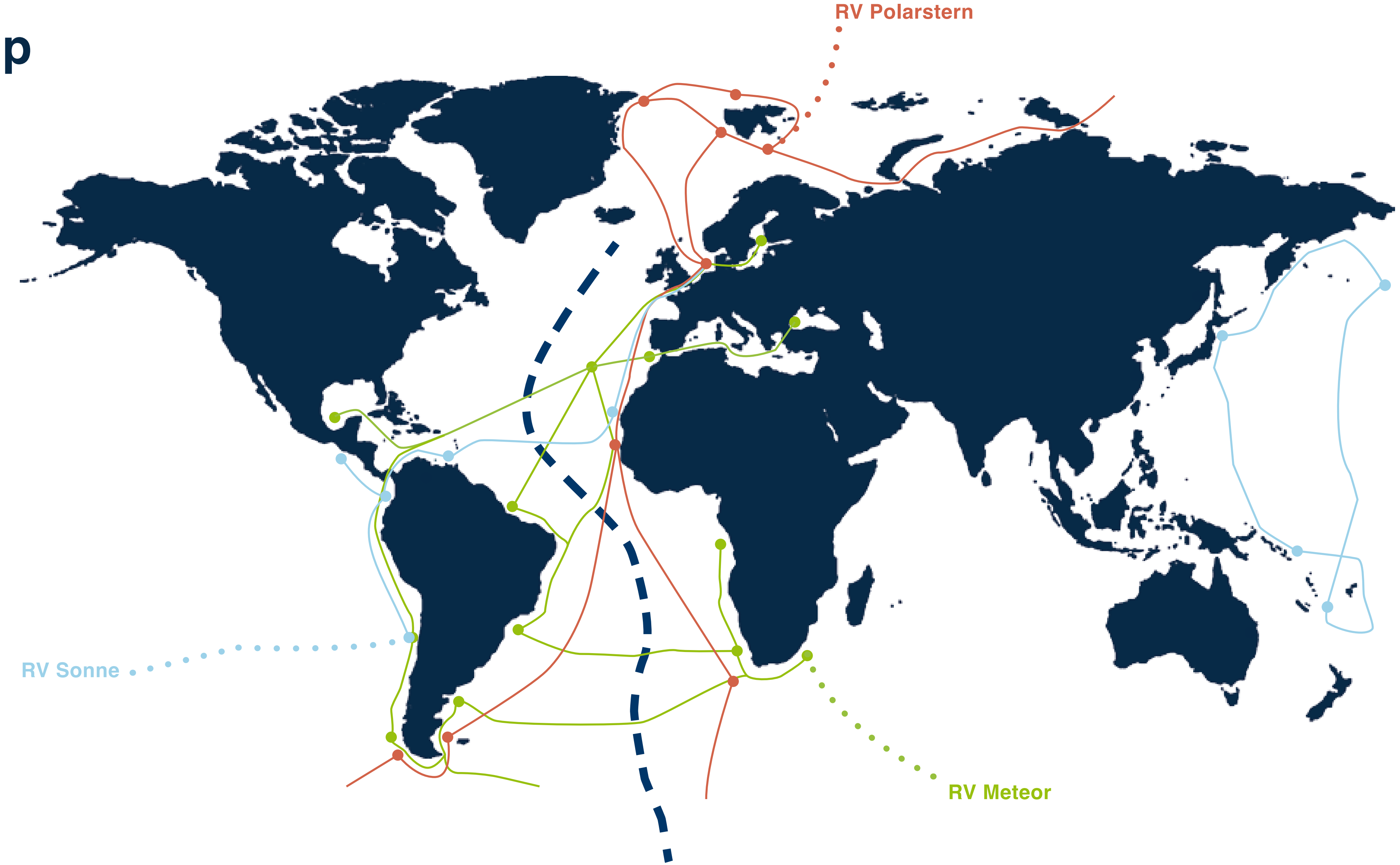
Bright aquamarine, scintillating turquoise, deep sapphire. Pleasantly lukewarm, refreshingly cool, freezing cold. The ocean is different everywhere. Upwelling occurs along the continental west coasts. Cool, nutrient-rich water rises towards the surface from the depths. Here, it helps many algae grow – a richly laid table for life in the sea. In the open ocean, on the other hand, the offerings are much leaner. Salt levels alter between the poles and the equator. From the top down to the bottom of the ocean, light rapidly disappears, the pressure rises and the temperature drops. Right at the bottom, in the sediment, there is often no oxygen just below the surface. And despite all of this, microscopic life goes on: Wherever they are, microorganisms have developed creative solutions to the challenges they face. Correspondingly, the locations at which we do our research also vary. We travel by ship from the North Pole through the tropics to the South Pacific, taking samples on beaches or on the open sea, from the surface of the sea and many thousands of metres down to the seafloor.

> 200 metres deep

The oceanic night begins. No light penetrates this far. It is cold, nutrition is scarce. Pictures from underwater cameras show that one only rarely encounters live organisms here. However, even in this underwater desert there are occasionally oases – for example at hot vents and cold seeps.

> 1/3 of the ocean surface

An ocean of superlatives: The Pacific is the largest ocean in the world, with the clearest of waters, and the South Pacific Ocean floor has the least amount of organic matter ever measured. We study how the smallest sea creatures survive in this seemingly endless and barren oceanic desert.



≈ 65,000 kilometres

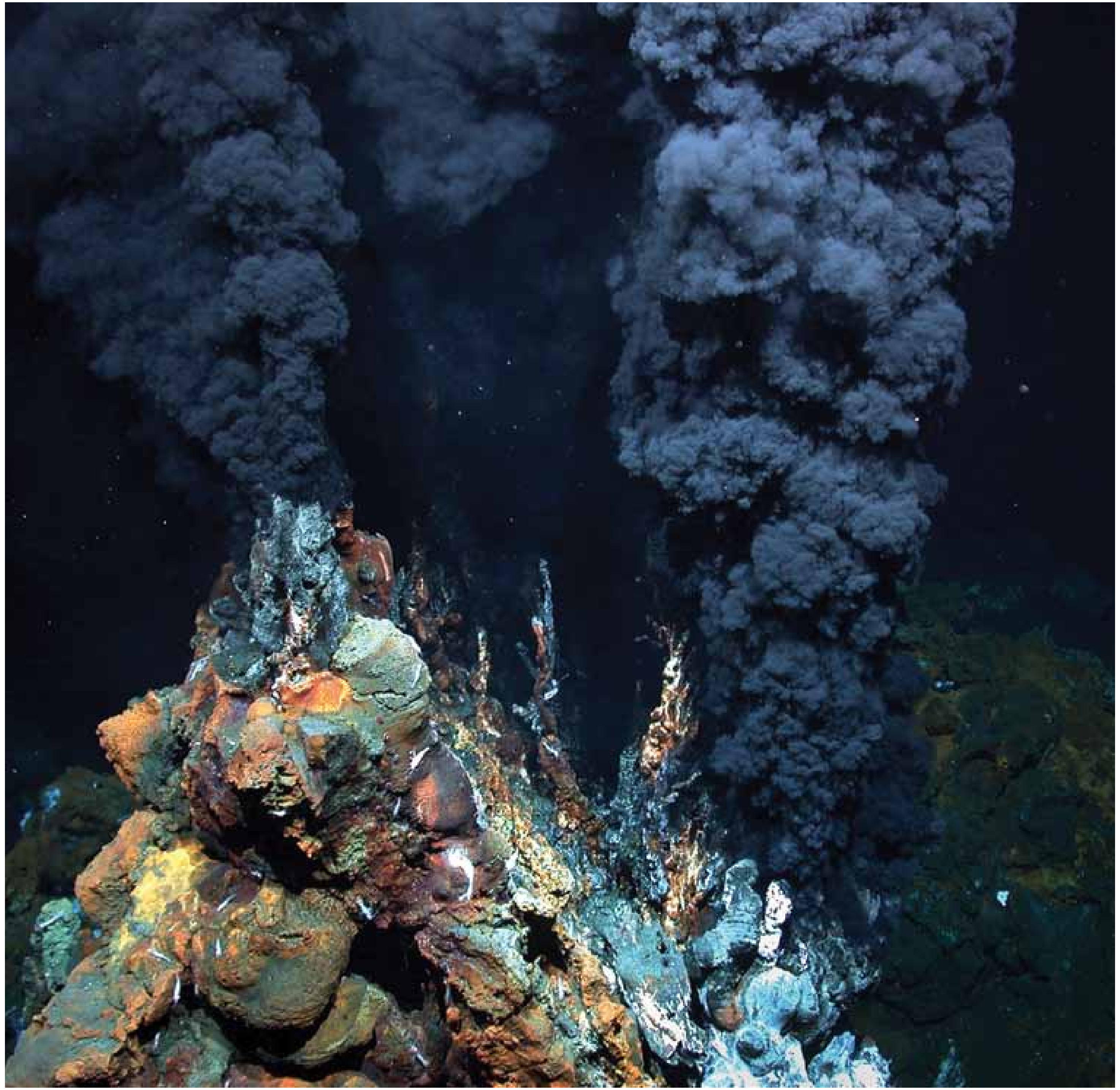
Like the seam on a baseball, mid-ocean ridges can be traced around the globe. Here, tectonic plates are slowly drifting apart. The Mid-Atlantic Ridge makes up nearly one third of all mid-ocean ridges, and we explore hydrothermal vents and their inhabitants from the Azores to south of the Equator.

> 300 °C

More than boiling: This is the temperature of the water gushing from black and white smokers on the seafloor. It doesn't bother some microbes, which can grow at temperatures as high as 120°C. On the contrary. They thrive around these deep-sea saunas.

> 42,000 sea miles

are covered every year by the large German research vessels on the world's oceans. They carry our scientists to the places that are at the centre of our research – from the North Sea to distant shores and the middle of the ocean, from the poles to equatorial latitudes: To better understand marine microbes, it is important for us to study them in their natural environment. We also collect numerous samples for analyses in our laboratory back home.

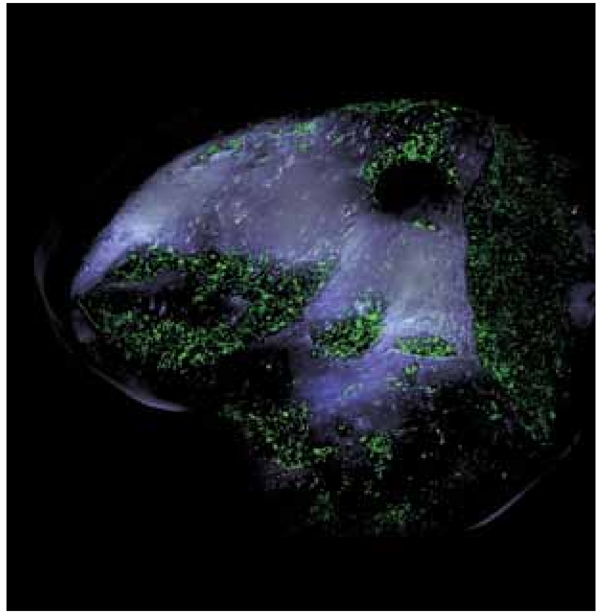


A question of taste

Some microorganisms are all-rounders. We can find them almost everywhere in the oceans. Others have clear preferences, for example with regard to temperature or oxygen levels. They can only be found where the conditions for them are just right. However, rare does not mean unimportant. We therefore not only study how abundant and widespread organisms are, but also how active they are. An example: Microorganisms that fix nitrogen. Some nitrogen-fixing species are extremely numerous, but barely active. Others are much rarer, but all the more active. They can truly fertilize the oceans.

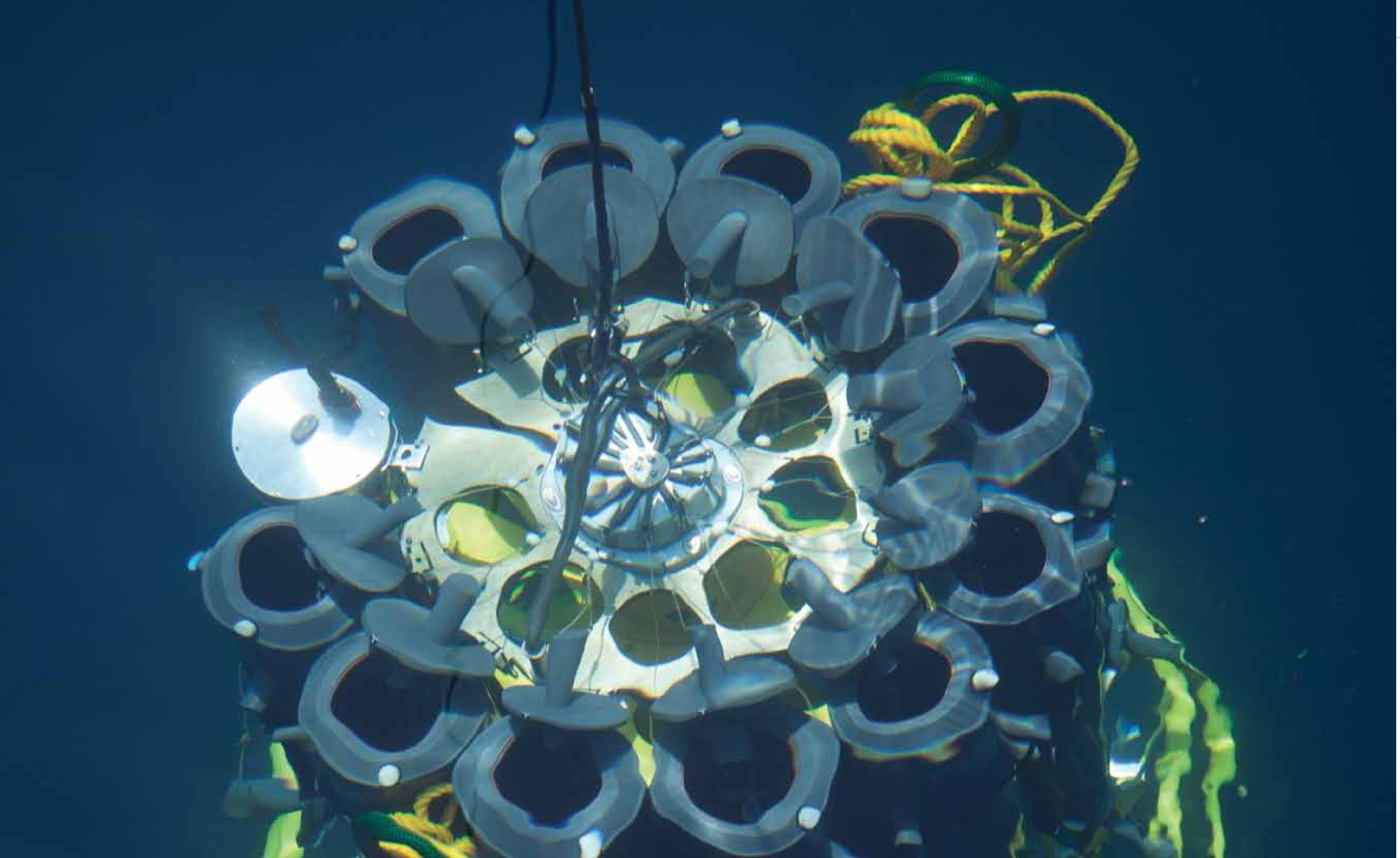
Oases of life in the deep-sea desert

Tectonic plates drift apart along mid-ocean ridges. Black smokers can occur here: Geothermal energy heats seawater deep below the seafloor. This water is rich in dissolved minerals and upon contact with the cold ocean waters at the seafloor, the minerals are precipitated and deposited, and metre-high chimneys form. Some microorganisms use the dissolved gases in the vent water as an energy source and form the basis for diverse and abundant animal communities – oases of life in the deep-sea desert.
Such oases can also be created differently: Cold seeps, for example, form where one tectonic plate is pushed beneath another. Methane escapes at numerous sites on the seafloor. Specialized microorganisms extract energy from the greenhouse gas methane and provide the basis for thriving ecosystems at these seeps. The methane-oxidizing microorganisms at seeps are critical for controlling the methane balance in the ocean. Elsewhere, there are underwater volcanoes that spew oil and asphalt. Here, too, many animals live in symbiosis with bacteria that can exploit chemicals in the oil. Even whale carcasses or sunken tree trunks can – for a limited time – provide enough energy and carbon for a rich variety of life.



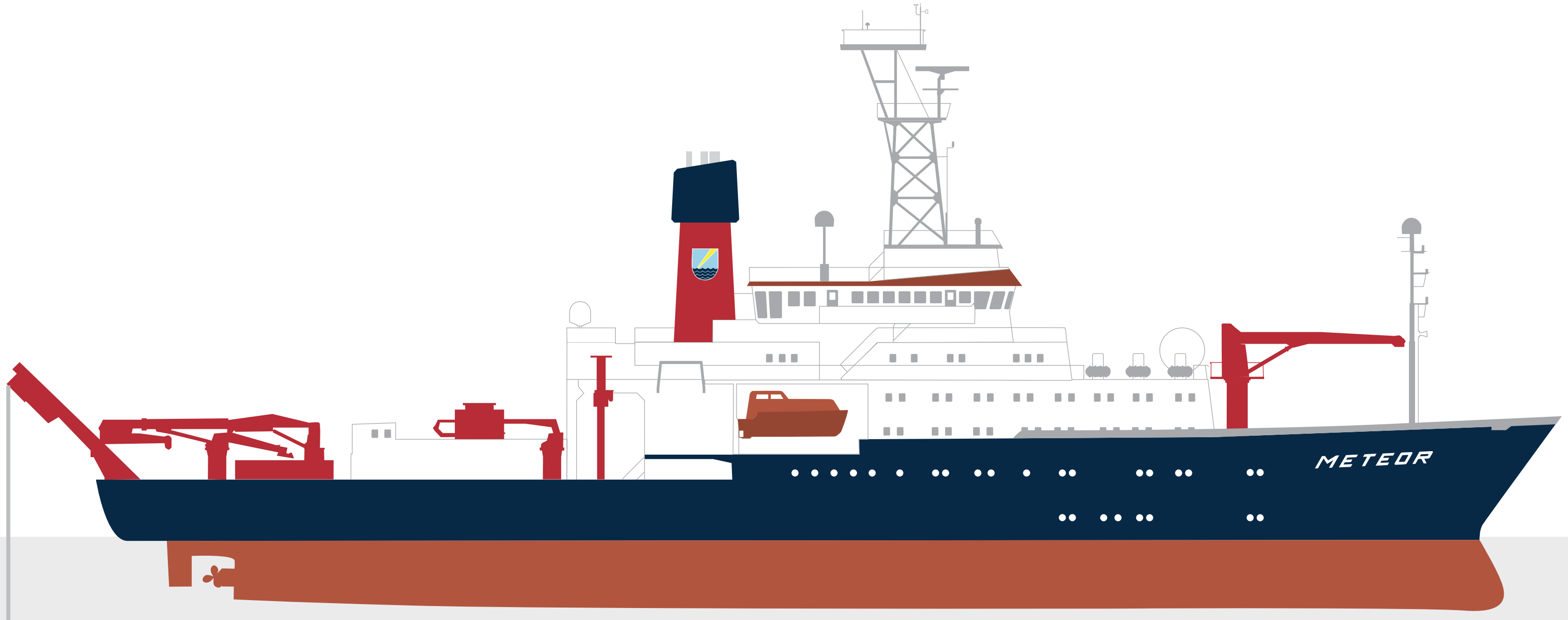
Withdrawn for protection
Dunes, mud, seals, lugworms – typical for most visitors to the North Sea coast. For us, in contrast, the beach is a large, open laboratory. We pay special attention to the coastal inhabitants living hidden from view in the mud: The bacteria in the sand. They do not colonize the grains of sand evenly. Exposed surfaces on the grains are almost uninhabited. The picture is quite different in the fissures and depressions. Here, they are gathered closely together. In such indentations, the microbes are well protected – for example, when water swirls the grains of sand around and rubs them against each other. Also, they are safe from animals that graze the sand for food.

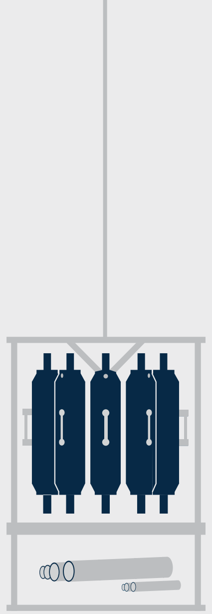
Beach with filter function
Some bacterial species can be found on almost all grains of sand. These regular players have a significant impact on the ecosystem: Many of the substances that are flushed with seawater into the sands do not emerge again (or are chemically altered). For example, the bacteria process both nitrogen and carbon compounds, thereby turning sand into an enormous, purifying filter. The microorganisms in the sand, for example, remove nitrate, which passes from agricultural land via rivers into coastal seas, and convert it into harmless nitrogen gas. Without this bacterial recycling, eutrophication of the oceans could occur, which would bring about a plethora of problems such as harmful algal blooms. Sands can thus protect the oceans from pollutant inputs from rivers.



How we study

Researching deeper thanks to technology: The world's oceans end when they hit continents, but these narrow coastal strips, the direct point of contact between the sea and the land, are just one of many microbial habitats we study. To reach the microcosmos in both the open and the deep ocean, we need our largest piece of equipment: Ships take us to our research locations. Even samples and measured data can only be acquired using sophisticated equipment. And once we have collected our water and sediment samples, it is important to make the microorganisms within them visible and, even more difficult, the internal structures within the microorganisms. Our challenge, then, is not just the research itself, but also how it can best be accomplished. Designing, building and developing new equipment and technologies is therefore an inseparable part of our scientific work.





≈ 60 weeks

is how long Tramper has already been autonomously on its way. Set down on the ocean floor at a depth of several thousand metres, this robot moves slowly forward and regularly measures the oxygen content in the seafloor. Its data provides information on local element cycles: Microorganisms break down organic material from the remains of dead plants and animals. The more organic material sinks down from the upper water layers, the more oxygen is consumed.

> 1 year

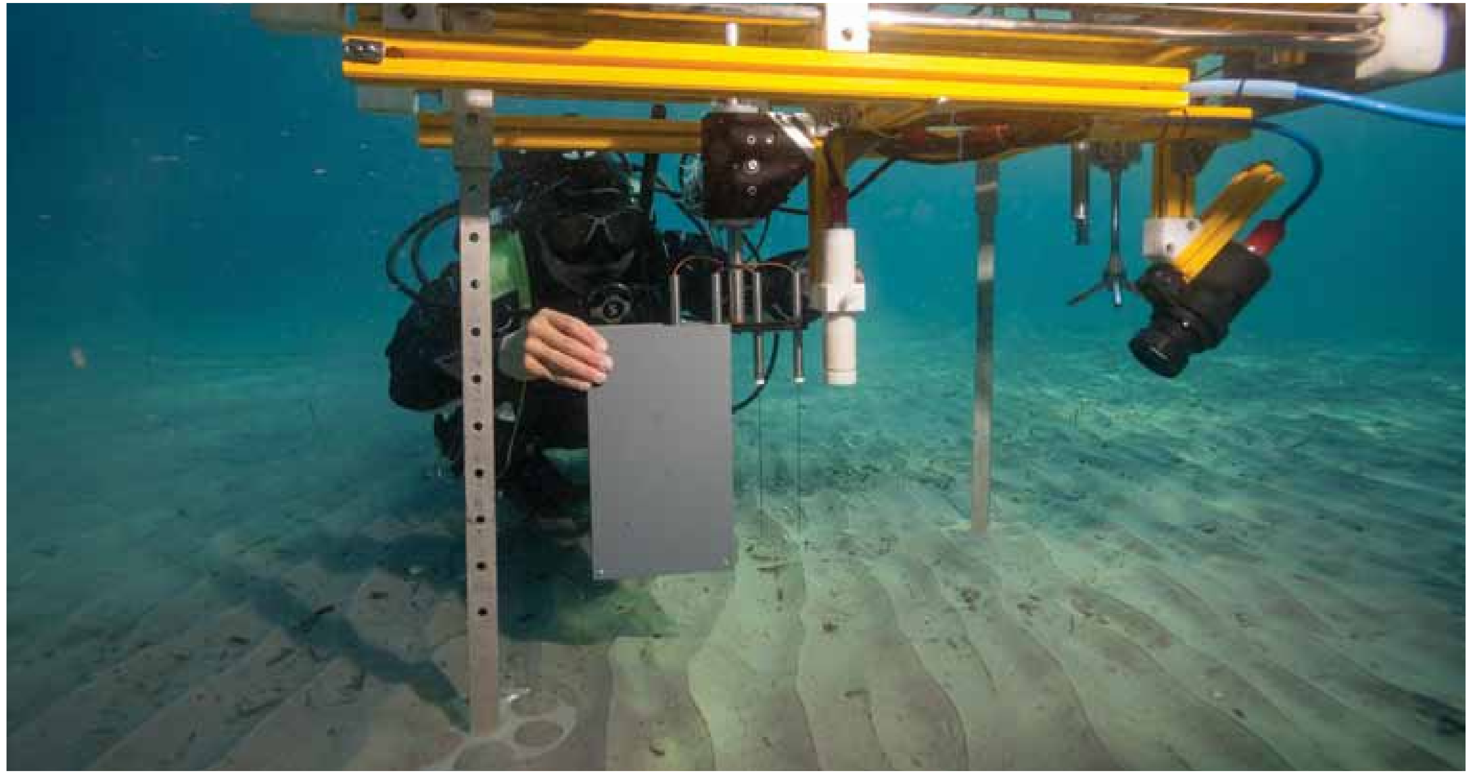
Good things take time. This is also often the case for research equipment. For example, it took a lot of employees and more than a year before Lance-A-Lot was ready for deployment. And we continue to redesign and develop it further.

Thousands of kilograms

How does research equipment get safely from the ship into the water and down to the seafloor? With a strong cable, for example. Which is itself a heavyweight: A 1.8 centimetre thick cable weighs 1.2 kilograms per metre. That adds up: To reach the bottom of a deep-sea trench, we must deploy almost 10,000 kilos of cable!

20 to 50 micrometres

Razor-sharp measurements: Our needle-like microsensors are generally finer than a human hair. Using these extremely thin glass capillaries, we can study the conditions in the smallest spaces and in the immediate environment of a single bacterium. For the sensors to be perfectly suited to our scientific needs, we build them ourselves.

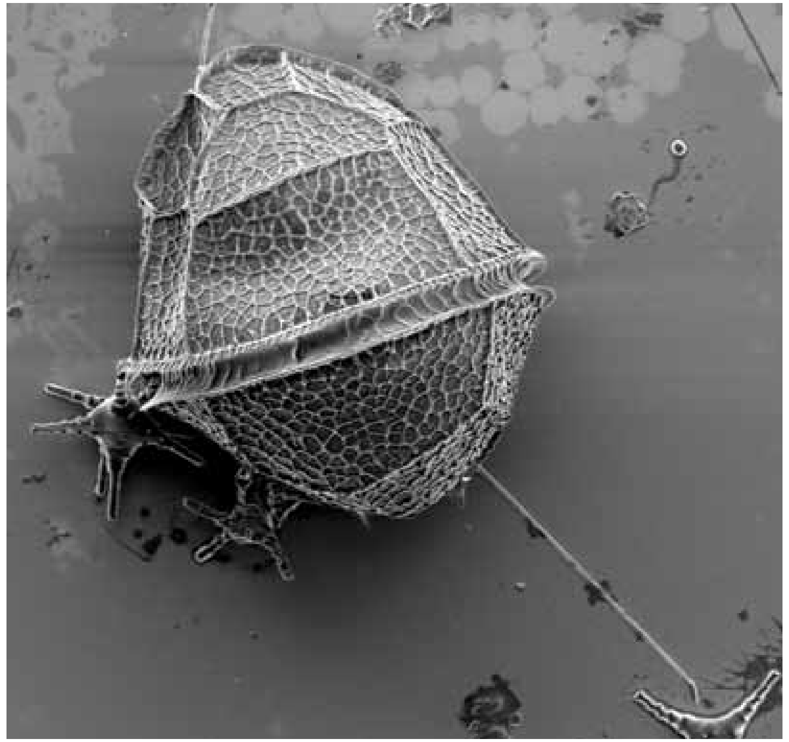


Super Zoom: Insights beyond resolution

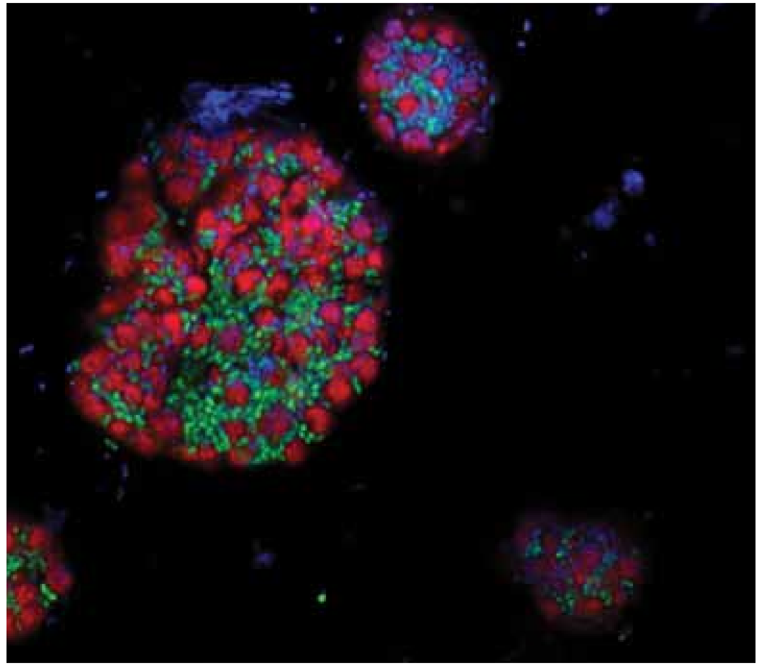
The majority of microbes are not visible to the naked eye. The microscope helps us to see individual cells. But we want to look even closer. Using high-resolution microscopes, we can even recognize the structures inside a microorganism. With the correct technology, even individual genes can be made visible! These objects are at the limits of resolution – the distance that two things must at least be apart to still be separated optically. Technical tricks make this possible: For example, we can make fluorescent molecules within the cells flash. Subsequent computer analyses generate an image that shows us exactly where the individual molecules are within a sample. This allows us to image cell structures approximately five to ten times more accurately than with conventional fluorescence microscopy alone.

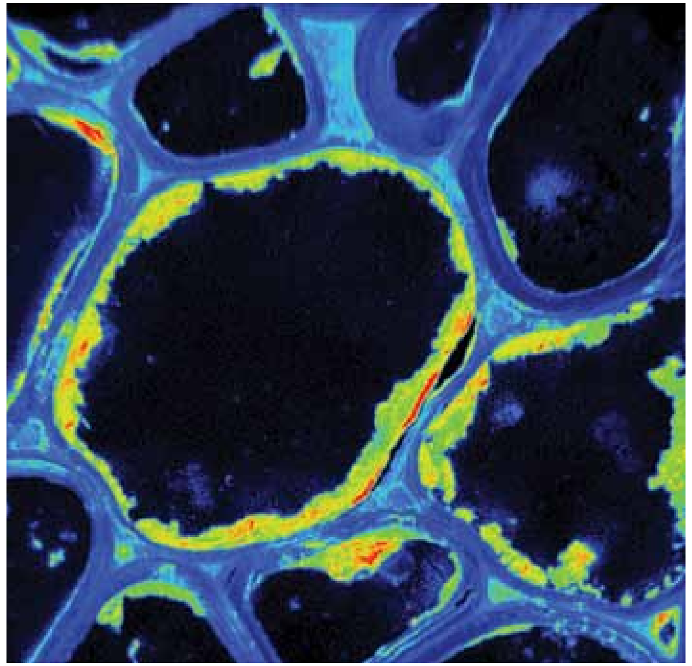
Lance-A-Lot: Triple investigation

Just like the legendary knight of King Arthur's Round Table, Lance-A-Lot has special powers: It simultaneously measures the flow velocity, the topography of the seafloor and oxygen levels in the sand. Where there are ripples, for example, oxygen and nutrients can penetrate deeper into the sediment than on a smooth surface. The microorganisms under ripples are therefore better supplied with nutrients. The flow rate in turn affects what and how much the bacteria breathe in the sand and what remains in the water.

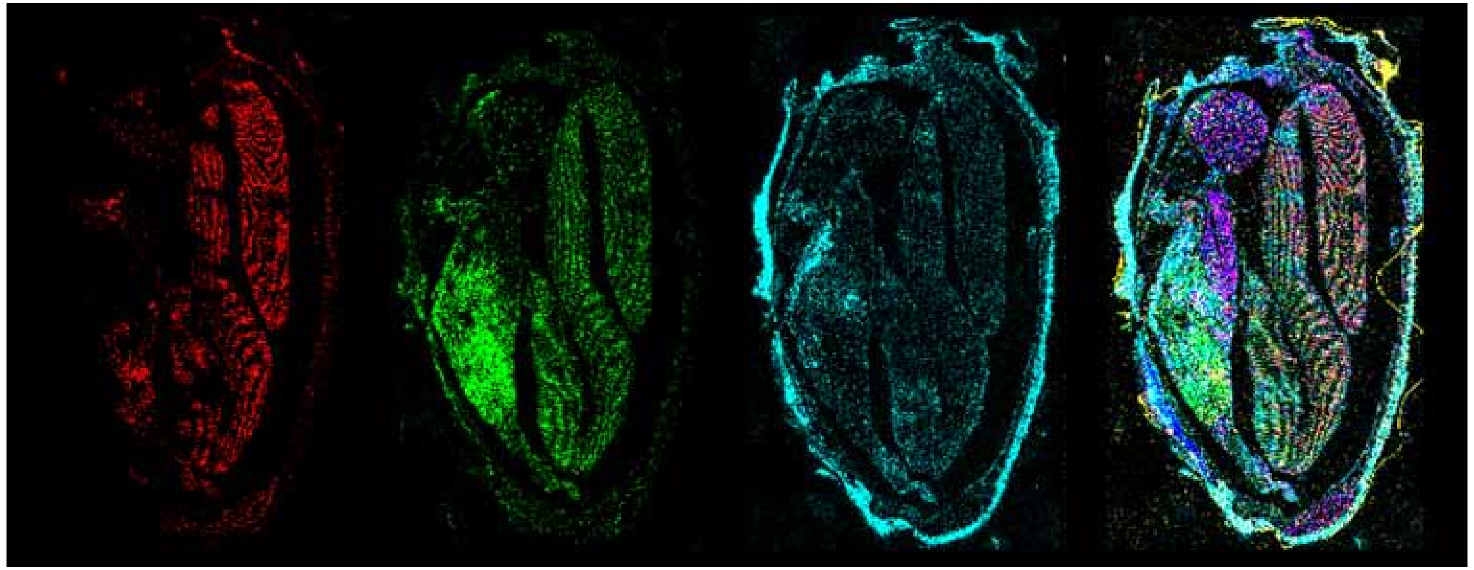


NanoSIMS: Viewed in detail
NanoSIMS stands for Nanoscale Secondary Ion Mass Spectrometer. This mass spectrometer possesses a special optical system that allows enormous spatial resolution: We can observe things as small as 50 nanometres – that is, a twentieth of a millionth of a metre. For example, we investigate the structures and processes in a single cell and can virtually watch it working. This is quite unique: There are only around 20 of these instruments worldwide. Ours was the first to be used to address ecological problems.



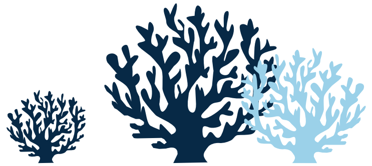


FISH: Identifying individuals
Microorganisms can barely be distinguished from each other based on their appearance. Nevertheless, every cell has its own fingerprint that is typical for the species – its genetic material. A case for FISH, Fluorescence In Situ Hybridisation. It selectively visualizes certain sections of the genetic material of individual cells. Under the microscope, these cells are then made to glow. FISH images of microorganisms look like a starry sky, but one with many different colours. Our question is: What is shining where? With FISH, we can precisely identify the organisms in our samples.



HyperDiver: Mapping reefs
Coral reefs are beautiful – and extremely sensitive. To protect them, we need to know them well and measure their health. But how? With our HyperDiver! It uses the colours of the corals: Their colour spectra are different depending on which species they belong to and their condition. HyperDiver monitors a wide range of wavelengths – many more than the human eye can perceive – and thus registers the condition of the reef. Image recognition and self-learning software evaluate the data. A diver can record up to 40 square metres of reef per minute with centimetre accuracy. A spin-off team from our institute has developed a user-friendly version of this technology and is currently commercializing it.

Mass spectrometry: Tracking individual molecules
The coexistence of microbes with each other or animals is all about molecules. From nutrition to communication, proteins, lipids and the like are almost always involved. We make these molecules visible and gain insights into the processes within cells and between cells. For example, our MALDI-MSI can visualize the distribution of thousands of molecular compounds, without having to stain or label them beforehand. This molecular microscope uses the molecular mass of the individual compounds. We then use the data to generate images from which we can identify which compound is where and how abundant it is. Other mass spectrometers use isotopes, which are different forms of the same element. For example, ratios of carbon isotopes reveal how microorganisms take up carbon dioxide – and thus provide insights into the global carbon cycle.



Bioinformatics: An ocean of knowledge
The genetic material of microbes, their DNA, conceals a lot of information about their lifestyle and abilities. To analyze the DNA, we would have to culture and investigate these tiny creatures in the laboratory – but this is not possible for most microorganisms. We therefore analyze environmental samples with all the microbes they contain. An enormous hodgepodge! We keep a clear view thanks to bioinformatics: For example, we analyze short pieces of DNA strands and then compile them to long sequences on the computer. Even the complete genomes of individual species can be reconstructed in this way. We gain in-depth knowledge about individual microbes from bioinformatics, but also of entire ecosystems.

Who we are

Microorganisms: They are so small that tens of thousands of them fit into a single drop of water. Without them, our world would not be what it is: At the Max Planck Institute in Bremen, we study microorganisms, the smallest inhabitants of the oceans. Which microbes live where, how and from what? What are their typical traits and properties? And what role do they play in biogeochemical cycles and thus for the environment and climate? At our institute, experts from very diverse scientific and technical disciplines search for answers to these questions. Most of our work is pioneering: To date, only an estimated one percent of marine microorganisms have been cultured and are well known. Again and again we discover new microorganisms with new capabilities – and thus gain fundamental insights and new perspectives.

Independently diverse

Our directors independently develop research goals and paths – a structure that makes the Max Planck Society a strong magnet for leading international scientists. This successful concept is evident in the many awards and prizes that value the work of our researchers – such as the Gottfried Wilhelm Leibniz Prize, ERC Advanced Grants and the Bergey Medal.

> 15 disciplines

Highly specialized and simultaneously interdisciplinary: Our researchers have in-depth expertise in their respective disciplines – and collaborate across the boundaries of their disciplines: From microsensors to microbiology, from geochemistry to genome analysis and from molecular ecology to mathematical modelling.

> 8,000 square metres

is the area occupied by our research – this includes laboratories, offices, workshops, technical building equipment and storage halls.

> 30 nations

People from more than 30 nations work closely together at our institute. In numerous projects, they collaborate with scientists from institutions around the world.

What else? Much more than science!
No science without non-scientists. The expertise and dedication of our many non-scientific workers are the cornerstones of our institute and crucial to our research success. With expertise and experience, perseverance and dedication, they make sure everything runs smoothly, from application to research trip and lab work to publication.

In-house equipment development
Tailor-made instead of off-the-shelf: Where we work, standard equipment is generally not good enough. High pressures, large temperature differences and the uncertainties of currents and waves – our equipment needs to withstand all of this. Our in-house workshops design, build and adapt, screw and solder – to develop the right instrument for our research.

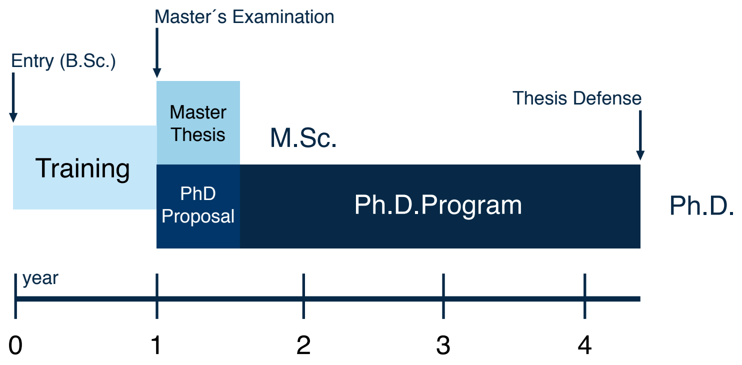
All-round excellence
Our librarian finds even the most hard-to-find articles and books. Our administration takes care of the institute’s finances, helps researchers apply for and manage their research funds and organizes our trips to the most remote places. Our IT crew ensures that our servers and computers keep running. Our building and technology services keep our laboratories and offices running. And our press team presents our research to the media and the general public.

MarMic: Our Master's and PhD programme

Researchers that study oceanic microbes have to look beyond disciplinary boundaries: Biologists, chemists, ecologists, physicists, informaticians, geologists and those from sub-disciplines from within each of these fields, need to cooperate closely. In MarMic, our International Max Planck Research School (IMPRS), we train young scientists to study our research objects from many perspectives. This, too, is teamwork: In addition to our institute, MarMic also includes the University of Bremen, Jacobs University Bremen and the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research.

MarMic accepts highly qualified and motivated national and international students. We are training a new generation of marine researchers to provide them with the knowledge needed to better understand microbial life and the way in which it affects our biosphere.

The beginning of the MarMic study year consists of lectures and seminars, internships and laboratory projects. As early as the end of the first year, students work on a research-based Master's thesis, which they complete after six months to gain their Master of Science (MSc). They can then go on to gain their PhD degree within another three years. Doctoral students participate in lectures, method courses, soft-skills training, international conferences, expeditions and an annual closed-session conference. Among other things, the programme aims to prepare students for their life as international researchers, which is why lessons are held in English.



How to find us
Using public transport, you can reach us from the airport and the main train station on tram line 6. Buses 21, 22, 28 and 31 travel to the MPI from other parts of town. Get off at the Universität Zentralbereich stop. From there it is a walk of around five minutes to the institute building (see site map on our website).

You can reach us via the A27 by car. Then take exit 19, Bremen Horn/Lehe, and follow the signs Universität onto the Hochschulring road. Turn left into Wiener Straße at the Hochschulring/Wiener Straße junction. Our institute is located on the right at the Wiener Straße/Celsiusstraße intersection.
If you are coming from the A1, change onto the A27 towards Bremerhaven at "Bremer Kreuz".

Coordinates
53° 6' 34,74'' N 8° 50' 51,251'' E

Information
Find out more about our research:
Website / www.mpi-bremen.de
Twitter / @MarineMicrobio
Facebook / @max.marinemikrobiologie
Youtube / @MPI Marine Microbiology
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Stephen Jay Gould, palaeontologist

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