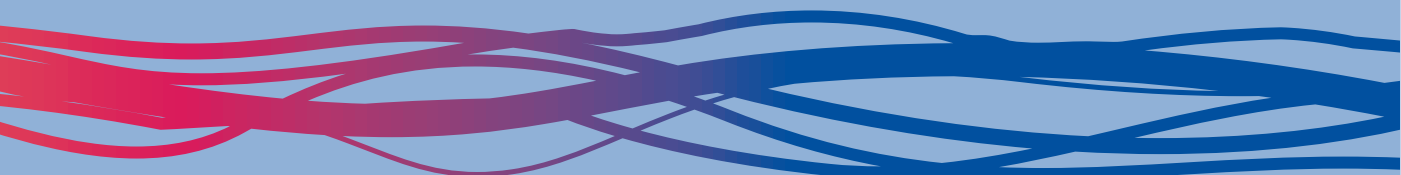




STEN CUTTING EDGE

RESEARCH FROM EUROPE'S OUTER EDGE

NORWEGIAN UNIVERSITY OF SCIENCE AND TECHNOLOGY





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A GLIMPSE FROM EUROPE'S OUTER EDGE

This book is a collection of stories from NTNU, selected to give you insight into some of our achievements during our 100 years as Norway's only science and technological university.

Researchers worldwide are on the hunt for new discoveries, energized by curiosity and a fascination with new ideas. I hope you'll explore our book with the same kind of energy.

Torbjørn Digernes

A handwritten signature in black ink, reading 'Torbjørn Digernes' in a cursive script.

Rector, NTNU

One hundred innovative years

Trondheim's rich research community has been the foundation for growth and innovation in Norway's businesses and industries over the last 100 years. Since its foundation in 1910, the university has educated tens of thousands of women and men as scientists, engineers, teachers, social scientists, architects, medical professionals and artists, all of whom have contributed to creating the Norway that we know today.

We celebrate our centennial year in 2010. We started as a technical institute in 1910, followed by the establishment of a teacher training college in 1922. Gradually we grew to include more and more disciplines and professionals. Today, NTNU's academic breadth includes everything from archaeology to the fine arts. We consider interdisciplinarity and academic diversity to be our primary strengths.

NTNU also prizes its position as an international university. Norway is totally dependent on the world at large, and we in turn make the contributions we can to the global community. Our strategic research areas tackle issues of worldwide interest, and our researchers thrive on projects that extend beyond national borders. This interdependence extends to our accomplishments over the last century. The close relationships that we have built with universities and industry at home and abroad are one important reason why we have been able to achieve the discoveries and accomplishments described in this book.

FACTS

The Norwegian University of Science and Technology (NTNU)

- 20 000 students – of which about 900 are international students
- 5300 employees (more than 1000 professors)
- Approximately 3300 degrees awarded annually — of which more than 300 are doctoral degrees

A scenic view of the Nidelva river in Trondheim, Norway, with the Nidaros Cathedral in the background. The river flows through the city, and the cathedral's tall spire is a prominent landmark. The scene is captured in a wide-angle shot, showing the river, the cathedral, and the surrounding greenery.

SMALL CITY — BIG UNIVERSITY

Trondheim's living river, the Nidelva, flows through the middle of the city, a place where NTNU researchers can even go fishing on their lunch break if they want.

is the centrepiece of the city, a symbol of Trondheim's 1000-year history as the religious centre of Norway. In town, you can swim at Norway's largest indoor pool or stroll past the city's 18th century wooden houses. Or take a short bus ride to the city's outskirts, where public forests are lined with trails for both summer and winter use.

Like most Norwegian coastal cities, Trondheim was always a market town. But in the 1600s, trade escalated as ships laden with timber, fish and copper sailed from its harbour south to Europe. This increased contact with other trading cities encouraged scholars on the outer edge of Europe to explore the wonders of their natural world. In 1760, the Trondheim Society, later the Royal Norwegian Society of Science and Letters, was founded. This was Norway's first scientific society, and can be considered one of NTNU's predecessors. Today, Trondheim's two sister institutions, NTNU and SINTEF, continue this long and honourable tradition in Norway's technology capital.



ACCOUNTING FOR THE ENVIRONMENT

In 2008, NTNU was voted Europe's best university for teaching sustainable development to engineering students. One reason is the university's industrial ecology programme, a unique marriage of economics and environmental accounting.

Industrial development is rarely seen as an environmental good. But using ecological principles makes it possible to examine exactly how industries affect the environment from a whole new perspective, and in doing so, to recommend beneficial changes.

In the early 1990s, industries began to search for ways to make their products and processes more environmentally friendly. At the same time, governments began to increase industry regulation. But accounting for the total environmental cost of different products made seemingly simple questions very difficult to answer: Does it make economic sense to sort garbage? Are biofuels really a green alternative?

A new kind of engineer

Norsk Hydro, a multifaceted Norwegian company that produces everything from aluminium to fertilizer, was one of the first to struggle to analyse its own operations in terms of pollution, safety and emissions. In 1993, company officials contacted NTNU's rector. Could NTNU train a new kind of engineer — one that could assess industry's environmental impact from a life cycle perspective?

NTNU administrators took up the challenge. Academics from MIT, Yale University and Georgia Tech contributed with ideas and advice, and by 1996, the first students had been admitted to the university's brand new industrial ecology programme. Two years later, the university created the world's first interdisciplinary industrial ecology programme, which admits both engineering students and social scientists. Collaboration with MIT has continued since the programme's inception. In 2006, the programme was transformed into an international master's degree. At the same time, interest in the subject exploded worldwide.



NTNU's industrial ecology programme was established when governments started to increase industry regulation. That forced industry to search for ways to make their products and processes more environmentally friendly.

A PERFECT MATCH

They're round, of perfectly equal size, microscopic, and kind of strange — but they could save your life.

They helped Trondheim resident Inger Lise Døvre when she needed a new heart. And they were invented by a determined professor in Trondheim.

Transplanting any kind of tissue from one person to another is one of medicine's biggest challenges. The body recognizes foreign organs and tries to reject them. Nowadays, doctors use drugs to suppress the immune system — but they can also increase the success of a transplant by matching tissue types between donors and recipients.

In the early days of organ transplantation, this was a difficult business — tissue typing tests took a long time and results were often unclear. All that changed when the microscopic beads invented by John Ugelstad, a professor at NTH (now a part of NTNU) came into medical use in the 1980s. Instead of long waits for unclear results, doctors suddenly had a tissue typing test that was nearly instantaneous and that literally turned green when the match was good.

So in March 2009, when Rikshospitalet University Hospital in Oslo rang Inger Lise Døvre, the Ugelstad beads enabled them to tell her they had found a perfect match.

Researchers are now using the beads to explore medicine's next frontier: immunotherapy. Several clinical trials are underway in the US to see if the beads can help in immunotherapy treatments for patients with HIV and bone marrow cancer.

And Ugelstad beads are moving from medical technology into nanotechnology, as NTNU and other researchers find new ways to put the beads to work. Flat-screen TVs and computer monitors are a first step, with other applications soon to come. Ugelstad beads — a perfect match for the 21st century.



Inger Lise Døyle was just 39 years old when she was stricken with severe heart disease. Three years later, she underwent a heart transplant that saved her life. Among the many medical technologies that make transplants possible is a tissue typing test that relies on polymer technology developed at NTNU.

THEY SAID IT COULDN'T BE DONE —

not on Earth, anyway. For American polymer scientists, the problem was gravity. For Professor John Ugelstad, the problem was solvable.

The Americans were right, sort of: the process of making perfectly round, perfectly uniform polymer micro beads ought to be affected by the pull of gravity. In theory at least, these tiny perfect beads could be made only in the weightlessness of space.

Ugelstad had worked cooperatively with John W. Vanderhoff, one of the leading American polymer scientists who had commissioned NASA's help. Ugelstad, however, saw producing the beads on Earth as a worthy professional challenge. After all, if the Americans were contemplating shooting scientists into space to manufacture the things, they clearly must have some practical value — although no one was sure at the time what it might be.

By 1977, Ugelstad had developed a two-step process involving a brew of microscopic polymer particles dispersed in water. The watery mix contained water-soluble organic compounds, which were absorbed by the particles as they swelled in a controlled, uniform way. Problem solved — Ugelstad could make the beads by the zillions. But what to do with them was another question altogether.

The next step

It took several other researchers and medical doctors to take the next step. One medical researcher in London felt if the beads could somehow be made magnetic, they could help with bone marrow transplantation. Coating the beads with substances that could act like a kind of glue for selected cells — like cancer cells — and then making the beads magnetic would allow cancer cells to be separated from healthy cells by using a magnet. Ugelstad and his colleagues solved this challenge in 1981.

The rest, as they say, is history. Patents followed, and companies were founded. From chromatography to tissue typing and immunotherapy, Ugelstad's magic beads have enabled medical advances far beyond what anyone could have guessed from when the first batch was made. It didn't take a space shuttle ride to make the beads after all. All it took was one researcher and a little determination.



100 INNOVATIVE YEARS



Commercial applications

Ugelstad beads have a range of commercial therapeutic applications from monitoring the health of HIV patients to diagnosing and treating cancer. HIV monitoring tests using the beads' unique characteristics are ideal for developing countries, because the tests only need a simple microscope to read the results.



**Professor
John Ugelstad**
(1921–1997)

SHARE AND COLLABORATE FOR SUCCESS

Shared staff and laboratories, collaborative projects, and a long and successful list of spinoffs all characterize the unique relationship between NTNU and SINTEF.

SINTEF was established by NTH (the Norwegian Institute of Technology, now a part of NTNU) in 1950, out of a desire to build a stronger connection between research and industry. SINTEF has grown to become Scandinavia's largest independent research institution, with staff from 67 countries. In 2009 these employees delivered products and services worth 2.6 billion NOK (325 million euro), of which roughly 15 per cent came from foreign commissions.

NTNU and SINTEF's tight partnership has put the two institutions at the forefront of international research in selected disciplines. This relationship between researchers at NTNU and SINTEF has also paid dividends at home: 90 per cent of Norwegian manufacturers rank NTNU and SINTEF as the country's most important technical specialists, and the best institutional collaborators. By bridging the gap between basic research and industry over the course of its 60 years, SINTEF has helped make many of Norway's most important research projects possible.

NTNU and SINTEF's close collaboration allows scientific groups with parallel interests to coordinate their efforts and share resources. NTNU personnel work on SINTEF projects, and many SINTEF staff teach at NTNU. Many NTNU PhD candidates conduct their research in partnership with one of SINTEF's numerous units.



The cooperation between SINTEF and NTNU is one of a kind, and the results include the development of research-based products. In this picture, fisherman Stian Furøy (right) is wearing a fisherman's suit developed at SINTEF. The suit boasts excellent buoyancy and is coloured in fluorescent yellow that is visible from a long distance. Researcher Ingunn Holmen Geving (left) is one of the developers behind the suit.

POWER TO THE PEOPLE

Norway has a long tradition of developing green, renewable energy. NTNU is at the forefront of developing renewable energy now and for the future.

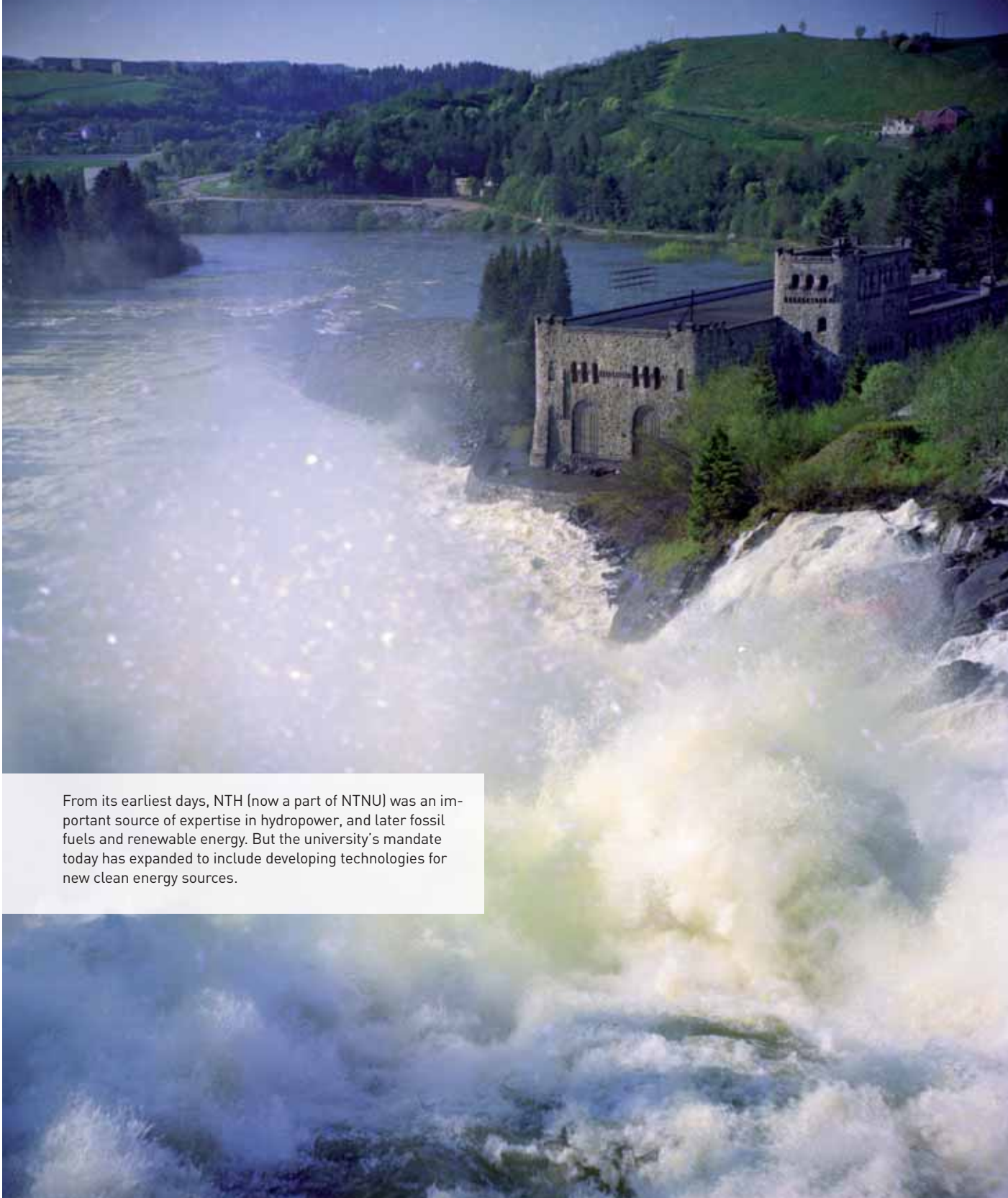
Sun: Energy from solar cells offers society a way to harness the inexhaustible power of the sun. NTNU and SINTEF have world-leading expertise in the production of crystalline silicon, the main material used in solar cell manufacture. The two institutions are working closely with solar cell manufacturers both in Norway and abroad.

Sea: Some experts would argue that the waves are a bigger potential energy source than wind. Since the 1970s, researchers at NTNU have developed methods that make it possible to produce energy from the mechanical effect of waves.

The ocean's own pulse — the tides — have also been a source of great research activity at the university. Work is now underway to develop turbines that will be installed in one of the world's first tidal power plants being built in Scotland.

Wind: Technology from NTNU is currently in use in several wind projects around the world — both on land and sea. Researchers are now tackling the problem of offshore wind farms with creative construction and installation ideas.

Air: A heat pump is almost too good to be true: Outdoor air is pulled through a heat exchanger equipped with a special fluid, and out comes air warm enough for your living room. The technology essentially transfers heat from one medium to another, cooling or warming air, depending upon the direction of the heat flow. Today, this approach is used in refrigerators and freezers, in car air-conditioning systems, and to heat water and buildings. Norwegian heat pump technology — largely developed by NTNU and SINTEF — is now in use everywhere from Japanese houses to the automobile industry.



From its earliest days, NTH (now a part of NTNU) was an important source of expertise in hydropower, and later fossil fuels and renewable energy. But the university's mandate today has expanded to include developing technologies for new clean energy sources.



Norway's rugged mountains and deep fjords create a landscape that is breathtakingly beautiful – and in need of protection. NTNU and SINTEF, NTNU's independent research partner, have been working to protect Norway's scenic beauty by making hydropower less of an eyesore. The result has been the construction of more than 600 underground hydropower plants worldwide, of which 200 are in Norway.

POWER IN EVERY DROP

Ninety-nine per cent of Norway's electricity supply comes from hydropower, which is one reason why the country ranks among the world's leaders in this area. NTNU researchers were crucial in developing Norwegian hydropower expertise – and now they're using that expertise to help other nations.

Norway's transition to a modern industrial nation began in earnest a century ago, with the harnessing of the country's largest waterfalls. Electricity was seen as "white gold" for a country that didn't have much more than fish to export. Hydropower did more than fuel Norway's early industrial growth: in 1891, hydropowered electric street lights were installed in Hammerfest, above the Arctic Circle. The installation was the first electric street lighting in all of northern Europe. Building hydroelectric plants was vital to bringing Norway into the 20th century.

With abundant, cheap electricity, Norwegian factories could produce nitrogen fertilizer using a technique patented by the Norwegian Kristian Birkeland. Abundant, cheap electricity also made it cost effective to ship bauxite to Norwegian ports to be transformed into the 20th century's wonder metal, aluminium. The pulp and paper industry could use hydropower to operate mills, drawing on the country's rich forests to produce paper for an ever-more literate world.

Educating hydropower engineers

This explosion in electricity demand created a need for knowledge and new technologies. As Norway's only technical college, NTH (now a part of NTNU), was given the responsibility to educate hydropower engineers. NTH hired its first professor of hydraulic engineering in 1912, only two years after it first began admitting students. Since then, hundreds of the university's hydropower graduates have helped strengthen Norway's position as one of the world's foremost hydroelectric nations.

Today, NTNU has expanded its efforts to help developing countries with hydropower. Nearly 80 percent of the doctoral research fellows at the Department of Hydraulic and Environmental Engineering's watercourse and water power group are from abroad, and nearly 500 hydroelectric engineers have graduated from the international Hydropower Development programme. Many of these engineers are an important resource for projects in their home countries.

COOLING A WARMING WORLD

This cow farts so much over the course of a year that she deserves her own listing in Norway's accounting of greenhouse gas emissions. There's not much we can do about that, unless we dramatically cut back on beef and dairy production. But industrial emissions are something we can control.

The Earth is wrapped in a blanket of greenhouse gases that makes our little blue planet inhabitable. These gases trap the Sun's heat and protect us from the deep cold of space. But too much of a good thing can be bad. Human activities over the last two centuries have now begun to truly increase the concentrations of these greenhouse gases by as much as 5 per cent. That may not seem like much, but it's enough to threaten the Earth's elegant temperature regulation system. A warmer world will result in altered rainfall patterns, melting ice caps and rising sea levels, which in turn will cause water crises, food shortages and plant and animal extinctions.

The biggest sinners

CO₂ currently represents 75 per cent of all greenhouse gas emissions. Here industry is one of the biggest sinners. For the last decade, NTNU and SINTEF have been tackling the challenge posed by the industry-related greenhouse gas emissions that waft out of smokestacks. This dedicated focus has paid dividends, and has built world-class expertise in Trondheim. As more and more countries agree to limit their greenhouse gas emissions, they'll need new technologies — technologies that are being tested right now by NTNU and SINTEF.

NTNU and SINTEF are working on a range of projects designed to reduce CO₂ emissions. A good example is the Research Centre on Zero Emission Buildings (ZEB). The centre's goal is to eliminate CO₂ that comes from every step of the construction process and during the entire lifetime of the structure, from the production of building materials to the building's layout and design.



Cows and other livestock account for approximately 18 per cent of all greenhouse gas emissions, according to the United Nations Food and Agriculture Organization. NTNU scientists don't work on livestock research, but their research on limiting industrial CO2 emissions should help control greenhouse gases from industry and energy production.

“WHY DON’T WE REMOVE THE CO₂, SEND IT TO THE BOTTOM OF THE SEA, AND STORE IT THERE?”

When NTNU and SINTEF researchers first asked this question in 1996 during the development of the Sleipner field in the North Sea, people thought they were crazy. Store CO₂ under the ocean? An interesting idea, but impossible.

Fast forward more than a decade and the impossible has become the ordinary. More than 10 million tons of CO₂ have been pumped into a “submarine” reservoir far below the Sleipner gas field. Sleipner was the first full-scale test of undersea carbon storage in the world.

Today, this same approach is in use the Snøhvit field in very northern Norway, where more than 700,000 tonnes a year of CO₂ will be piped back down to the undersea gas reservoir for storage. These efforts were only possible because of NTNU and SINTEF, which are considered among the leaders in developing the technologies we need for the capture, transport and storage of CO₂ from coal and gas power plants, as well as from oil platforms and process industries.

These pioneering efforts have also helped transform the city of Trondheim into a European hotbed for CO₂ science, with an annual research budget topping 20 million euros. Five CO₂ research laboratories are being built in the Trondheim region, through the European Strategy Forum Research Infrastructure. NTNU and SINTEF are also involved in 10 different EU projects on CO₂ capture and storage — the most of any European research group.

Some said CO₂ capture and storage was impossible. But all that CO₂ locked away under the North Sea says otherwise.



Trondheim's research community is a pioneer in CO₂ handling. Technology developed here makes it possible to send 700,000 tonnes of CO₂ a year into a submarine reservoir below the Snøhvit gas field in northern Norway.

DO YOU UNDERSTAND ME?

NTNU researchers are helping to provide the keys to unlock the secrets of different African languages, by supporting the work of students who are native speakers.

Franklin Arhinful, Evelyn Anane and Cynthia Kumah came from Ghana to NTNU to study linguistics. The diversity of Ghana's more than 60 languages poses intriguing challenges that the three master's students hope to help solve. Arhinful is studying communication via the radio, found in every Ghanaian's home. Ten years ago, most radio communication in this West African coastal country was in English, a legacy of the British Empire. But now, radio broadcasts in local languages and dialects are flourishing. For her part, Anane is working on compounding in word formation in her dialect, while Kumah is helping to create the first-ever dictionary for her dialect.

Invaluable knowledge

Researchers from NTNU's Department of Language and Communication Studies have a long history of working with far-away lands on linguistics. Master's students from Uganda, Ethiopia, Malawi and Ghana have come to Norway to share their invaluable knowledge of African languages or dialects. In turn, they gain valuable experience from linguists at NTNU. It may seem odd to bring students from Africa to Norway to study the native tongues they have left behind. But students say travelling to Norway to study has sharpened their views of their own languages and land.

"It has really broadened our minds," Anane says. "You have to explain the culture and the language." All three believe that improving the linguistic understanding of Ghana's different languages is vital to keeping country's diverse cultures alive. "Language helps transmit traditions from one generation to the next," Kumah says.



Franklin Arhinful (from left), Cynthia Kumah and Evelyn Anane came from Ghana to NTNU to pursue master's degrees in linguistics. Ghana is home to more than 60 different languages and dialects.

“CAPITALISM CREATES PEACE”

Norway has long been known as a nation that works to promote peace, whether it's in mediating Middle East talks or in its role in awarding the Nobel Peace Prize. But sometimes to promote peace, you have to understand war.

Indra de Soysa is professor of political science and director of NTNU's Globalization Programme. Along with colleagues at NTNU and the International Peace Research Institute in Oslo (PRIO), de Soysa has made a thorough study of the effects of globalization on internal conflicts. His simple findings may be surprising to many: "Capitalism creates peace."

"When we look at all the factors that contribute to preventing conflicts, economic freedom is very important, even in relation to other factors such as good governance, democracy and human rights," he says.

Economic freedom counts

De Soysa and his colleagues have concentrated on PRIO's comprehensive database of conflicts from 1970 onwards. The researchers compared this to data that describe economic freedom, and checked a number of other variables that are relevant in reducing or sharpening the danger of armed conflict. Simply stated, de Soysa says, "economic freedom counts more than factors such as democracy and good governance when it comes to preventing armed conflict."


Those findings should be of use to countries like Norway in designing aid for lesser developed countries. "If we want to contribute to peace and development, it would be better to help to build functional markets that make it profitable to invest in productive activities rather than in armed conflict," he says.

As the forces of globalization bring different cultures together, or as businesses extend their economic reach into distant countries or cultures, questions inevitably arise: what is the most ethical way to respond? Sometimes, the answers are counterintuitive, as de Soysa has found: To understand the global, you have to understand the local.

Better transportation systems and new, lightning fast communication technologies have made the world a smaller place. NTNU's interdisciplinary Globalization Programme's main focus areas are: conflict and migration; global production and communication; and intercultural dynamics-communication, responsibility and development.

Photo: A bike platoon north of Kilinochi, SRI LANKA.



A young child wearing a red long-sleeved shirt, blue jeans, and a dark bucket hat is standing in a field of tall grass. The child is holding a fishing rod with both hands, and the rod is angled upwards towards the right. The background is a soft, hazy sunset sky with warm orange and yellow tones. To the left, a portion of a person wearing a patterned garment is visible. The overall mood is peaceful and nostalgic.

Norway's 40-year history as a petroleum nation was the result of both luck, in having the petroleum in the first place, and skill, in developing the technologies needed to extract petroleum resources from the depths of the Norwegian Sea.

CATCHING FISH TAKES SKILL AND TECHNOLOGY

The same is true for other natural resources, such as oil and gas.

Norway has been blessed with great natural resources, and today Norwegians are living well because of them. Luck, you think. And yes, that's true — but the day we found oil on the Norwegian continental shelf, no one quite knew how to extract these vast resources from the harsh North Sea.

Today, few countries in the world have used their natural resources as prudently as Norway. This was not just luck, but the result of knowledge, skills and technology. The day we found oil was also the day that engineers and scientists across the land took up new and exciting research. The results have enabled us to safely and cleanly extract oil and gas from under thousands of metres of water, at the bottom of the sea. NTNU and its research have been at the very core of this technological achievement.

Opportunities and challenges

The first commercially viable oil deposit was discovered on the Norwegian continental shelf in 1969. For a small country like Norway, the find offered great opportunities, but also tremendous challenges. Many doubted that the country could build the skills needed to run the oil business.

Johannes Moe, then-rector of NTH (now a part of NTNU), had no doubts. He saw possibilities where others saw limitations, and created a study programme in petroleum engineering. This was in 1973. The following year, 20 petroleum engineers had completed a retraining programme and were ready for battle.

Johannes Moe had a strategy. In 1978, he convinced the authorities to pass a stringent requirement for any company that wanted to operate on the Norwegian continental shelf: At least 50 percent of the research for the field development had to

take place in Norway. This resulted in an avalanche of inquiries to NTNU and SINTEF.

Fully 40 years have passed since Norway became a petroleum nation in its own right. In cooperation with the petroleum industry, NTNU and SINTEF have provided fundamental expertise in multiphase and seismic research, concrete construction, and drilling technology. We are among the best in the world in petroleum engineering and are one of the industry's major suppliers of scientific know-how.

More recently, however, our focus has changed. From a one-sided focus on research related to increased production of fossil fuels, we are now equally committed to developing technologies that help to make oil and gas operations greener.

Concrete achievement

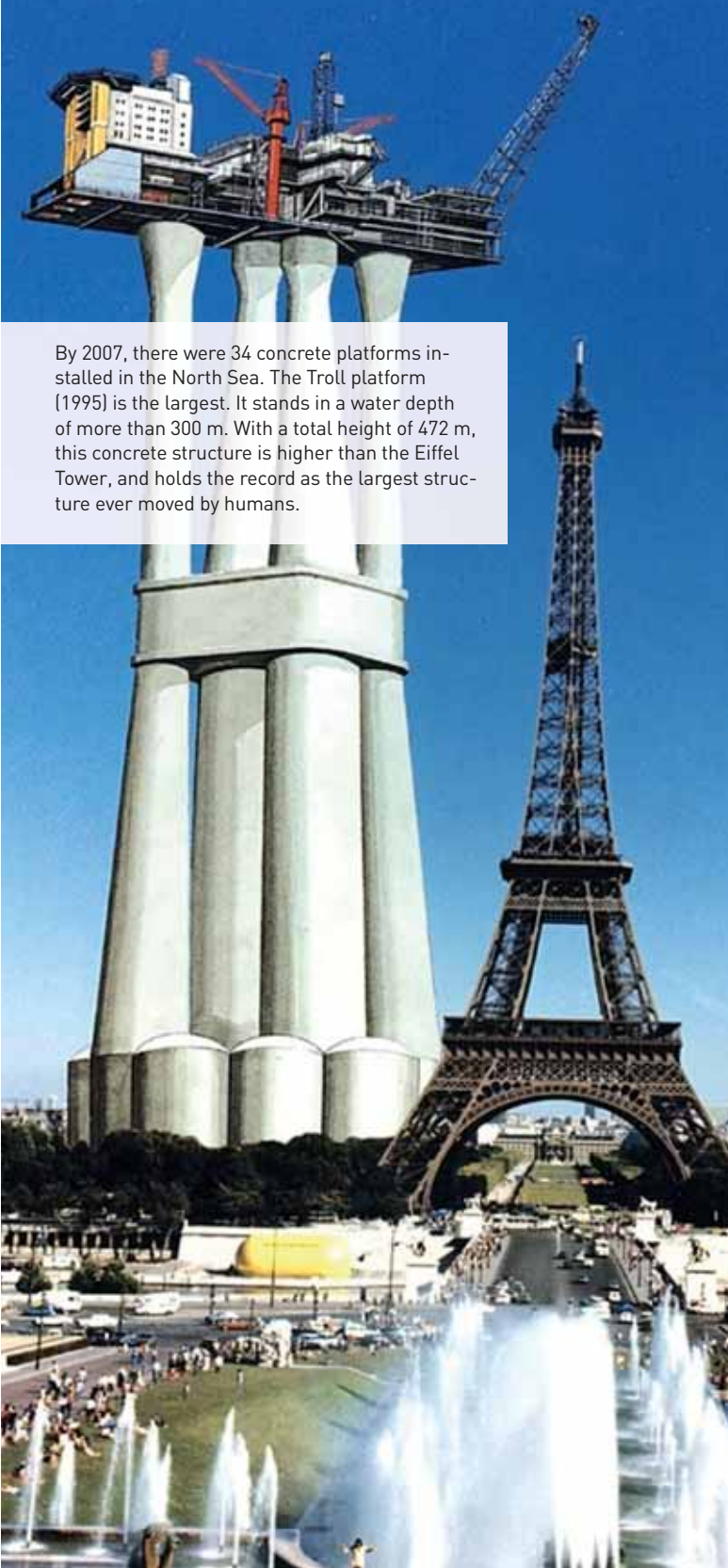
OK, we found oil. To extract it we needed to build oil platforms. But what kinds of structures would be strong enough to withstand the extreme weather of the North Sea?

In 1970, Norwegian engineers were already highly experienced in the use of concrete, both for port facilities and bridges that faced tough weather conditions. They knew the challenges involved. When the first Norwegian concrete offshore platform was proposed, however, the international petroleum world was sceptical. The standard oil platform was generally built from steel.

A research report from NTH eased the concerns of sceptics. It described how concrete structures along the Norwegian coast tolerated environmental and mechanical stresses very well. The result was the introduction of new international regulations for the use of concrete in offshore structures. The first concrete offshore structure, the Ekofisk tank, was installed in 1973.

As more and more oil fields were discovered in deep water, researchers redoubled their efforts to create the best possible concrete for the job. By 2000, NTNU researchers had developed concrete that was twice as strong and tough as concrete from 1970.

Norway's concrete research, and the construction of massive offshore structures, has garnered widespread international recognition. Today, this expertise is used to build concrete structures across the globe.



By 2007, there were 34 concrete platforms installed in the North Sea. The Troll platform (1995) is the largest. It stands in a water depth of more than 300 m. With a total height of 472 m, this concrete structure is higher than the Eiffel Tower, and holds the record as the largest structure ever moved by humans.

100 INNOVATIVE YEARS



Making platforms obsolete

Multiphase technology enables the mix of oil, gas and water that is commonly pumped from an oil well to be carried, unseparated, in a single pipe to land. It sounds simple, but it isn't — and yet it has revolutionized oil and gas production. This ability to carry everything in one pipe has made expensive processing plants that used to be built on oil platforms obsolete. It's also the reason why two of Norway's newest and biggest petroleum fields, Ormen Lange and Snøhvit, can be operated without a platform at all. Instead, both fields are connected to land by long multiphase pipes in excess of 120 kilometres long.

Horizontal drilling

Drilling technology developed with the help of NTNU has also made it possible to develop oil fields that were previously considered unprofitable. One such technique is called horizontal drilling, which boosts the extraction rate from each field. The technology also makes it possible to extend the reach of the drills that are deployed from each platform, making it unnecessary to establish as many drilling points on each field. Horizontal drilling enabled the extraction of nearly 2 billion barrels of oil from the Troll gas field that previously were considered unprofitable to extract.

Waste materials make concrete stronger

As late as the mid-1970s, silica dust spewed out from the ferro-alloy industry and polluted the communities where the industry was located. Fine silica dust proved to be a waste product that was difficult to handle. But NTNU researchers found a way to turn this problem into an useful product: Adding an optimum amount of silica dust to concrete made the concrete considerably stronger. It was this discovery that gave Norway's concrete expertise a technological edge.

Safer every day

Nowadays, more and more oil exploration and production take place on the bottom of the sea. The most dangerous work is done by underwater vehicles and machines, operated remotely from control rooms on land. In the long run, letting remote controlled vehicles do the work is cheaper, safer, and makes better use of the experts who work in the control room.

Safe on land, a handful of experts in production equipment and subsea geology can operate an undersea oil field from the control room with the click of a mouse. It looks like they could be playing computer games, but the visuals on their screens are the real thing – the links and controls to wells, drills, pumps and pipes that extract oil and gas from hundreds of metres below the sea. Welcome to a modern-day oil "platform", where the biggest risk the crew runs is from clicking a mouse.

From an advanced control room, operators work with a big screen that shows real-time data from the seabed along with models of the actual petroleum reservoir. They can also hold conference calls with geologists and other experts while they're operating the field. This 21st century approach to oil exploitation is called "Integrated Operations", or IO. NTNU's Centre for Integrated Operations is a cooperative effort with SINTEF and IFE, the Institute for Energy Research, and is supported by the Research Council of Norway and 11 companies.



NTNU's innovative research was critical in enabling the development of the Snøhvit gas field – Europe's largest energy project. One of Snøhvit's production facilities is called Melkøya, Europe's first large-scale liquefied natural gas (LNG) production plant. The Snøhvit field lay untouched for more than 20 years after it was discovered, because it was considered too costly and challenging to develop. But the advent of new LNG technology, which cools the natural gas into liquid form, enables gas from Snøhvit to be pumped into tankers and transported to markets in the United States and Europe. Statoil Chief Olav Fjell has said that without NTNU Professor Einar Brendeng's foresight, vision, and dedicated research, Snøhvit would have never become a reality.



Alginates are used in ice cream, jams and light margarines to keep them from being excessively runny. At some point, though, hot weather triumphs over chemistry.

DESIGNER MOLECULES

Call them wonder molecules: Alginates, polysaccharides extracted from seaweed, help keep the foam on beer and form the bubbles in champagne. Researchers at NTNU are at the forefront in the search for new uses for this natural biopolymer.

While alginate's two components, mannuronic acid and guluronic acid, were discovered by German researchers in 1955, it was biotechnology researchers at NTNU who took up the challenge of probing the basic secrets of alginate properties. Alginates can be gelatinous or runny, they can sink in water or float — all depending on the way that the two components are arranged in this giant linear molecule.

NTNU scientists discovered the enzymes that make it possible to control an alginate's composition. With these enzymes and other chemical tools, scientists can create designer alginate molecules with precisely the composition and properties they want. Combining these specially designed alginates with stem cells may offer new hope in the treatment of diabetes patients and in the treatment of broken bones or severed nerves.

Tricking the immune system

Our immune system is programmed to recognize new cells as foreign, which causes it to attack. Researchers at NTNU have specially designed a robust alginate capsule that can hold and camouflage foreign cells and thus fool the immune system. This approach may be a lifesaver for the many diabetes patients who depend on insulin injections to survive. By acting both as an "immune barrier" and as a "tea bag", the capsules protect transplanted insulin-producing cells while being porous enough to release vital insulin into the body's bloodstream. The capsule has been named TAM – the Trondheim Alginate Microcapsule.

Alginate research in Trondheim started in 1949, under the Norwegian Institute of Seaweed Research. Today, research continues at NTNU's Department of Biotechnology and the Norwegian Biopolymer Laboratory (NOBIPOL).



Holey different

How is it possible to make such beautiful artwork out of an enormous metal plate with thousands of big and little holes? Using a variety of perforation tools and hand power, Anne Karin Furunes surprises and amazes with her unusual technique. The artist, who is a professor of fine art at NTNU, has had individual exhibitions in New York, Venice, Rome and Sydney. Her most well-known work in Norway is a 500-metre long picture that hangs along the train tracks in Oslo.



WHAT DO THESE TWO MEN HAVE IN COMMON?

The younger man has been a successful pro football player. The older man can boast that he has the same conditioning as a 20-year-old. Their common denominator? A training method developed at NTNU.

It's not just top athletes and fit retired people who have seen impressive results using the NTNU method, called 4x4 training. It has also proven to be particularly effective for people who need to improve their overall fitness to have a better and healthier life.

Cardiac patients, patients with chronic obstructive pulmonary disease (COPD) and people who have had hip replacements have improved their overall fitness after only a few weeks of training.

Several of the world's best football clubs, including Real Madrid, Barcelona and Celtic FC, have also used this approach — and have seen very good results over a relatively brief period. Other followers include Olympic gold medalists in cross-country skiing, Beckie Scott from Canada and Charlotte Kalla from Sweden.

Professors Jan Helgerud and Jan Hoff are the dynamic duo behind the method. Through years of research on how exercise affects the heart, they have developed the “perfect” training method. The 4x4 approach stimulates the heart to take up and metabolize oxygen more quickly. This is critical to improving overall fitness because it is often the heart, not the muscles, which limits the body's ability to perform.

The method is extremely simple. In short, you increase both endurance and strength with the magic 4x4 approach.

Want to try yourself? See the description on the next page.



Professor Emeritus Sverre Myklestad (78) has the same oxygen uptake and heart capacity as a 20-year-old. He has followed the "4x4-training method" during regular interval training sessions since 1986. Harald Martin Brattbakk has played for Celtic FC, FC Copenhagen, and Rosenborg. He is Norway's highest scoring footballer of all time. Brattbakk has used the 4x4 method throughout his career.

SMART EXERCISE WITH THE “4X4-METHOD”

It is important that you customize your workout according to your physical condition. You should exercise two to three times a week to achieve results. You can follow your endurance workout with strength training.

Endurance

- Warm up 6–10 minutes
- Run or walk up a steep incline. Exercise hard, but at an even pace for four minutes, then take an active break for three to four minutes. Repeat the pattern four times
- At the end of each hard workout session you should reach 85–95 percent of your maximum heart rate. That means you should be breathing hard, but should not be completely out of breath, and you should feel that you could continue with the same effort for at least another minute

Strength

- Repeat each exercise four times in four series
- Use heavy resistance — after the fourth repetition you should not be able to do more
- Leg presses or squats are the most important exercise
- You should increase the amount of effort needed in each session to perform each exercise.



100 INNOVATIVE YEARS




Making athletes even better

A great wax job on your skis, perfect ski jump techniques and great coaches: when Norwegian athletes perform their best, NTNU has helped make a difference. NTNU researchers test everything from ski waxing methods to ski jumping techniques, they have also developed a programme to educate elite athlete coaches in cooperation with the Norwegian School of Sports Science and the national Olympic Sports Centre.

Blowing in the wind

Many Norwegian athletes who have been on the podium during the Olympics and World Championships have also been in NTNU's wind tunnel to test their aerodynamic resistance. Information from the wind tunnel has helped ski jumpers, alpine skiers and cyclists. The tunnel is also used to develop equipment, including better ski jumping boots and ice skating suits. The 11-metre-long, two-metre-high, three-metre-wide structure is also used to measure how wind affects oil rigs, cars and bridges.

A photograph showing a young woman with blonde hair, wearing a grey t-shirt, singing with her mouth wide open. A man with glasses and a checkered shirt is standing behind her, holding a white ultrasound probe against her neck. The probe is connected to a machine with a monitor displaying a blue-toned image. The setting appears to be a laboratory or a clinical room with a white ceiling and fluorescent lights.

Ultrasound researchers in Trondheim don't just work with physicians, but also with singing teachers and music professors. By combining ultrasound images, acoustic recording, voice analysis and muscle measurements, researchers have developed a method of finding out what happens when we sing. Here voice student Maren Myrvold sings opera, while Professor Hans Torp operates an ultrasound probe.

ULTRA-DEEP INSIGHTS

A revolutionary collaboration between physicians and engineers at NTNU has given us amazing pictures from inside the body — images that have helped many people and saved many lives.

Today, doctors can remove a brain tumour with their eyes fixed on a screen, they can see clear images of an embryo only five weeks after conception, and they can observe a foetus as a detailed 3D image. All this thanks to a unique multidisciplinary working environment which has developed innovative solutions that result in the best possible medical treatment.

The story of this unique collaboration began in the early 1970s, when Professor Bjørn Angelsen and the Departement of Engineering Cybernetics developed Doppler technology to measure how fast blood flows around the heart.

Ten prototypes

In the summer of 1976, researchers built ten prototypes of an ultrasound instrument. One of the doctors who participated in the testing of the devices was cardiologist Liv Hatle. She combined the use of Doppler technology and ultrasound in the diagnosis of cardiovascular disease, and was an international pioneer in the use of this technology. Gynaecologist Sturla Eik-Nes was also among the collaborators. In 1978 he came up with a method where blood flow to the foetus could be measured using ultrasound. This also attracted international attention.

These discoveries were the start of a unique interdisciplinary ultrasound working group composed of researchers from NTNU, SINTEF and St. Olavs Hospital. The company Vingmed Sound joined the collaboration in the 1980s, resulting in the development of many more amazing methods and technologies. Together, this diverse assemblage of medical doctors and engineers has brought Norwegian ultrasound technology to the very forefront of both research and product development.

An ultrasound stethoscope

Vscan is the world's first hand-held ultrasound device. The invention combines ultrasound technology with cellular technology and was ranked as the 14th most important innovation in the world in 2009 by TIME Magazine.

Vscan can see into many parts of the body. The small device can provide images of the heart and liver, and can see what is going on inside the mother's uterus. Its handy size and the simple user interface provide general practitioners and ambulance personnel the ability to provide fast and thorough medical care. The invention is different from a "normal" ultrasound machine in several ways: It is not a complete ultrasound machine, but the picture quality is good and it is easy to use. Vscan has only one button: Press it, and the picture comes up.





The development of Vscan was led by Professor Hans Torp, here together with PhD student Ole Christian Mjølstad.

100 INNOVATIVE YEARS



Medical Technology – an NTNU Strategic Area

The successful cooperative between physicians and engineers at NTNU and SINTEF has been formalized as a separate strategic area, where physicians, biologists, engineers and social scientists work together to solve common problems. In recent years, researchers in the strategic area have been joined by colleagues from the disciplines of medical technology, molecular biology and nanomedicine.

What makes ultrasound so well-suited for medical use?

The secret behind ultrasound is the pulse of high-frequency ultrasonic sound waves that is sent out and then echoes back. The time that it takes for the echo to return determines the distance to its origin. These signals are converted by an ultrasound machine into anatomical images of various organs. The best-known application of ultrasound is in foetal imaging and diagnostics, but the technology can also be used to study the heart, liver, abdomen, breast, prostate and thyroid.

THE SOUND OF TRONDHEIM

Norwegian jazz has become one of the country's most visible and recognizable export products. If you have listened to Norwegian jazz, you have also heard the sound of Trondheim — a product of 30 years of graduates from NTNU's Jazz Performance Programme.

The music has been described as surprising and tasty, engaging and provocative. It's no accident that jazz students from NTNU create this kind of sound — their work has developed out of 30 years of improvisation and listening, and hard practice. The result has been the export of Trondheim's distinctive sound, carried by the musicians who have become a part of the larger world community of jazz.

The tuba isn't generally thought of as integral to jazz, but Trondheim musicians have created a sensation with their innovative use of this big instrument. Kristoffer Lo plays his tuba in the place of a guitar bass in PELbO, a trio. Øystein Baadsvik also plays the tuba, but is one of few tubaists who has established a solo career. "Baadsvik shows that anything a violin can do, a tuba can do, too," wrote *The Daily Telegraph* after one of his concerts in England.

Both bands and individual musicians from NTNU's Jazz Performance Programme have garnered international attention: In 2005, saxophone player Kjetil Mørster won the award for the year's best international jazz talent under 30. The following year, trumpeter Mathias Eick brought home the prestigious award.

Kristoffer Lo, a graduate of NTNU's Jazz Performance Programme, plays the tuba in place of a bass guitar in the jazz trio PELb0. The trio's music eliminates the boundaries between jazz and rock.



THANKS FOR THE MEMORIES

It could affect your mother, your uncle — or it could affect you. An estimated 35 million people worldwide suffer from memory disorders like Alzheimer's disease, a number that could reach 115 million by 2050.

"Memory," observed the British writer Oscar Wilde, "is the diary that we all carry about with us." But what if that diary is somehow lost or erased? As the world's population ages, more and more people will be afflicted with Alzheimer's disease and other memory disorders. Understanding how the healthy brain works is the key to treating these neurological illnesses — or perhaps even preventing them.

Parsing the complexities of the human brain is a task that is usually only achieved one step at a time. But neuroscientists at NTNU took a giant leap forward when in 2005, they discovered the equivalent of a biological GPS in the brain that keeps track of where you are and where you have been. Another discovery in 2009 of how the brain separates different information may expand our understanding of schizophrenia in the brain.

Mapping the secrets of your brain

In 1996, two young Norwegian researchers chose Trondheim as the place to establish a fledgling laboratory with one overarching goal: understanding exactly how your brain works. Today, May-Britt and Edvard Moser's lab has grown to become the Kavli Institute for Systems Neuroscience, one of just 4 such Kavli neuroscience research centres worldwide.

Jan Henry T. Olsen, former Norwegian Minister of Fisheries in Norway, was struck by Alzheimer's disease when he was only 51 years old. Here he is pictured with his wife, Laila Lanes. To shed light on this difficult disease, they wrote a book entitled "Hurry to Love" which was published in 2009.



NTNU was only supposed to be a waystation on the Mosers' academic journey. Five years in Trondheim, and then onward, out into the academic world.


But the Mosers were charmed by Norway's third-largest city, and their research animals, laboratory rats, seemed happy, too. They won support for their rapidly growing lab, first from NTNU and from the Research Council of Norway. The lab's staff grew from just two — the Mosers — to a team of more than 50 researchers.

It was the discovery of grid cells, though, that really put the Mosers' research "on the map" — both literally and figuratively. These cells measure distances, figure out how far you have gone, and compare where you are to a mental map that was made the last time you were there. Understanding the way the brain stores these memories in neural networks is critical to figuring out what happens when things go wrong, as with Alzheimer's disease and other memory-related afflictions.

A switching mechanism

In 2009, Kavli researchers discovered a switching mechanism that the brain uses to filter out distracting thoughts so it can focus on a single bit of information. The researchers think the switch is a general approach employed throughout the brain to enhance interregional communication. The malfunctioning of this switch may also help explain what goes wrong in schizophrenia.

Now the Mosers and their research teams are branching out into the use of genetic tools and computational analysis to go beyond their discovery of grid cells and spatial navigation. The hope is that these tools will help them unlock the secrets that have tantalized both philosophers and scientists over the centuries: How the brain sorts and reassembles the sounds, smells, images and tastes that together with our memories and experience compose the fabric of our lives.

A photograph of May-Britt Moser, a woman with dark hair wearing a white lab coat over a pink shirt. She is looking down at a small white rat with black spots that is standing on a transparent platform in a dark environment. The rat is holding a small object in its mouth. The background is dark, and the platform is made of clear glass or plastic.

May-Britt Moser is co-director of NTNU's Centre for the Biology of Memory and Kavli Institute for Systems Neuroscience. Researchers use laboratory rats to understand the workings of the brain in creating mental maps and memories.

100 INNOVATIVE YEARS



Neurons, synapses and more

The normal human brain is made up of about 100 billion nerve cells (neurons). Each neuron can have roughly 10,000 -20,000 points of contact with other nerve cells. These contact points are called synapses, and are where memories are stored. If one nerve cell wants to send information to another nerve cell, it generates an electrical signal that is sent through a nerve fibre to a synapse. Kavli researchers work by detecting and analysing these electrical signals in the brain.

BRINGING THE WORLD TO TRONDHEIM

A successful university sends its graduates out into the world to tackle global challenges. But every other year, NTNU students turn this model on its head, and bring the world's students to Trondheim with the goal of making the planet a better place.

ISFiT — the International Student Festival in Trondheim — is the world's largest student festival with a thematic focus. It takes a legion of NTNU student volunteers — about 350 in all — to choose issues, design workshops and select the 450 participants who will travel to Trondheim for the event. Recent speakers have included His Holiness the Dalai Lama, former Director-General of WHO Dr Gro Harlem Brundtland and Nobel Peace Prize Laureates Dr José Ramos-Horta, Professor Wangari Maathai and Betty Williams. The festival itself awards a student peace prize to highlight the struggle against international injustice.

Since 1997, student organizers have also taken a more active role in building the foundations for peace by bringing together students from opposing sides of conflicts for a week of common experiences. Students from hot spots as diverse as Rwanda, Kashmir, Sri Lanka and the Balkans have all been represented since the start.

ISFiT may be the largest international student festival organized by NTNU students, but it is not the only one. Since 1917, students in Trondheim have arranged a cultural festival called UKA. Its name in Norwegian means "the week", which reflects the fact that the festival was originally a week-long fundraiser designed to help students build and maintain the university's Student Union building. UKA has now grown to be Norway's single largest music and cultural festival, with 80,000 tickets sold during the three weeks of the festival.



Every other year, 450 students from around the globe assemble in Trondheim to tackle some of the planet's most challenging problems in the largest thematic student festival in the world.

LIFE HAPPENS — SO DO DISEASES

Lifestyle diseases are among the major health challenges facing modern society. But what if we could prevent them, as well as detect and treat hereditary diseases long before they become a problem?

Understanding the genesis and development of disease takes the power of numbers — biological and chemical information from hundreds of thousands of samples to help researchers identify trends and factors that protect people from some diseases or predispose them to others.

Starting in 1984, NTNU medical researchers began to build one of the world's most extensive modern biobanks. Now with biological material from 250,000 participants — everything from DNA samples to vials of blood — along with thousands of questionnaires on lifestyles choices — researchers can use the NTNU biobank to better understand just what keeps us healthy — or not.

Unique in a global context

The breadth and depth of the material is unique in a global context, giving scientists worldwide the opportunity to study how genetic variation, lifestyle and behaviour affect health and disease over time. In the long run, it will also give us a better understanding of the diseases that are harder to prevent — those that are in our genes.

The major donors of this extensive biological collection are the residents of the Norwegian county of Nord-Trøndelag. These residents account for roughly 100,000 samples, collected over the course of 25 years in what is called the HUNT study, Norway's largest health study. The rest of the material represents a collection of health data and blood samples from a number of other Norwegian health surveys.

The HUNT study has helped illuminate new relationships between different health risks. Thanks to HUNT, for example, we now know that obesity increases the risk of depression and that smoking is more dangerous for women than for men.



Susceptible to
diabetes

Susceptible to
arthritis

Susceptible to
hip dysplasia

THWARTING CYBER CRIMINALS

The millions of bits of information we send over the Internet every day carry vital information: medical records, a visa application, or maybe even your latest tax payment. This new digital world is not without its criminals, though. In the US alone, roughly 10 million Americans were subject to some kind of identity theft, and the costs of cyber crime are estimated to exceed \$50 billion per year.

Part of the problem is that sending information securely over the Internet involves balancing two conflicting demands: the information has to be fast and easy to send, but it also has to be safe. That's where researchers at NTNU's Centre for Quantifiable Quality of Service in Communication Systems — Q2S — come in.

The key's the thing

Q2S researchers have created a way to transform the information you want to send over the Internet into small secret packages that just you and your recipient's computer can encrypt and decode. The Q2S approach is 10,000 times faster than current techniques for decoding information and 17,000 times faster in encrypting it.

Another Q2S program is a finalist in a highly visible international competition sponsored by the US government to develop a new cryptographic hash function for digital signatures. A hash function can take a text of any length and produce a short string of bits to represent the text uniquely. It offers your computer a way to check to see that the text being sent has not been changed, and it can be used as a digital signature.

The Q2S entry Blue Midnight Wish was one of just 14 submissions to make the second round in the US competition. It could be the next world standard for digital signatures and message authentication.

The funny thing is, the better Q2S researchers do their job, the less likely users are to know that they're doing it. That's how it is supposed to be: fast and secret.

Q2S is a Norwegian Centre of Excellence, supported in part by a 10-year grant from the Research Council of Norway. Its scientific staff of 52 professors, PhD candidates and postdocs conduct research on network media handling, quality of service mechanisms for dynamic networks, and quality assessment.

> Access Denied

International prize to architecture students

TYIN Tegnestue, a non-profit humanitarian organization run by two NTNU architecture students, won the ArchDaily Building of the Year 2009" for its project called "Safe Haven Library" (picture) — a library built for the Ban Tha Song Yang orphanage in Thailand. The competition is organized by ArchDaily, the world's largest online architecture magazine.



OVERCOMING THE CHALLENGES OF THE SEA

Oil installations worth billions of dollars need maintenance, and vulnerable resources must be monitored. Working at sea is costly and difficult, and sometimes dangerous. The more we can hand over to technology, the better.

Norway has always been a marine nation, and NTNU has played an active part in that history. In the 1960s and 1970s, researchers from NTH (now a part of NTNU) and SINTEF, the university's independent research partner, helped develop advanced automation systems to improve the competitiveness of the Norwegian merchant fleet.

The next era began in the early 1970s, with oil and gas discoveries on the Norwegian continental shelf. This time, NTH and SINTEF pioneered groundbreaking approaches to dynamic positioning, which enabled ships and other offshore structures to stay exactly in place without anchoring, in spite of the forces of winds, waves and weather.

Now marine Norway is on the threshold of a new period, one in which surface installations for oil and gas development are replaced by sea bottom structures that are remotely operated and maintained. This new technology has been key to unlocking petroleum resources in the frozen north of the Arctic and Barents Sea. Unmanned vehicles like autonomous submarines, can be used to perform both routine missions and dangerous operations. Ultimately, this new technology reduces both costs and the risks to human life.



One of the most important contributions that NTNU has made to the offshore industry is a control technology that allows vessels and drilling rigs to keep a steady course and stable position without setting anchor.

With technology as an anchor

The sea is always in motion. That makes it nearly impossible to lay pipes, drill wells, and operate, maintain and produce oil from the ocean's greatest depths.

"Dynamic positioning" enables vessels to stay in place with pinpoint precision, no matter the weather. The positioning system's "brain" uses advanced control technology, based on complex calculations with data collected from a gyro compass, GPS and acoustic transponders on the ocean floor. Wind and water strength and movement are also factored into the calculations. The system controls the positioning of the vessel with different kinds of propellers.

This technology was first used by dive boats in the North Sea and is now standard equipment on nearly all offshore vessels.

Professor Jens Glad Balchen at the Department of Engineering Cybernetics at NTH was the first to begin research on dynamic positioning in the 1970s. A cooperative agreement with Kongsberg Våpenfabrikk, NTH and SINTEF led to the commercialization of the system under the name "Albatross" (now known as "Kongsberg Dynamic Positioning").

In 1999, Norway's largest technical trade magazine, *Teknisk Ukeblad*, named the invention the century's second biggest Norwegian engineering feat, beaten only by the Troll platform, the 472 metre high, 656 000 tonnes platform that produces gas from the Troll field.



The drive to understand how ships and other ocean structures behave in the open ocean is at the heart of the interdisciplinary research at the Centre for Ships and Ocean Structures (CeSOS). The centre's scientists explore both theoretical and experimental questions using the world-class facilities at the Marine Technology laboratories.

100 INNOVATIVE YEARS



World-class ocean engineering group

The Centre for Ships and Ocean Structures (CeSOS) is a world-leading research group focused on ships, platforms and other ocean structures. The centre's motion control technology for unmanned vessels is unique in the world.

CeSOS researchers use theoretical and experimental methods in hydrodynamics, structural mechanics and control technology to develop new knowledge about how ships and other structures behave in the ocean. The unique hydrodynamic laboratories at the Marine Technology Centre are important elements of this research.

The centre is highly interdisciplinary: Half of its researchers have a background in marine and marine technology, while the other half has a background in disciplines such as structural and electrical engineering, cybernetics, mathematics and other sciences.



The GSM system makes it possible to send information from Norway to New York in a few seconds. The technology that makes this system so robust and secure was developed by NTNU and SINTEF.

"HELLO MUM. HOW'S THE
WEATHER IN NEW YORK?
PLEASE SEND MONEY...
LOVE, LUCY. "

The world has become smaller — and the technology that has helped bring this about was developed in Trondheim.

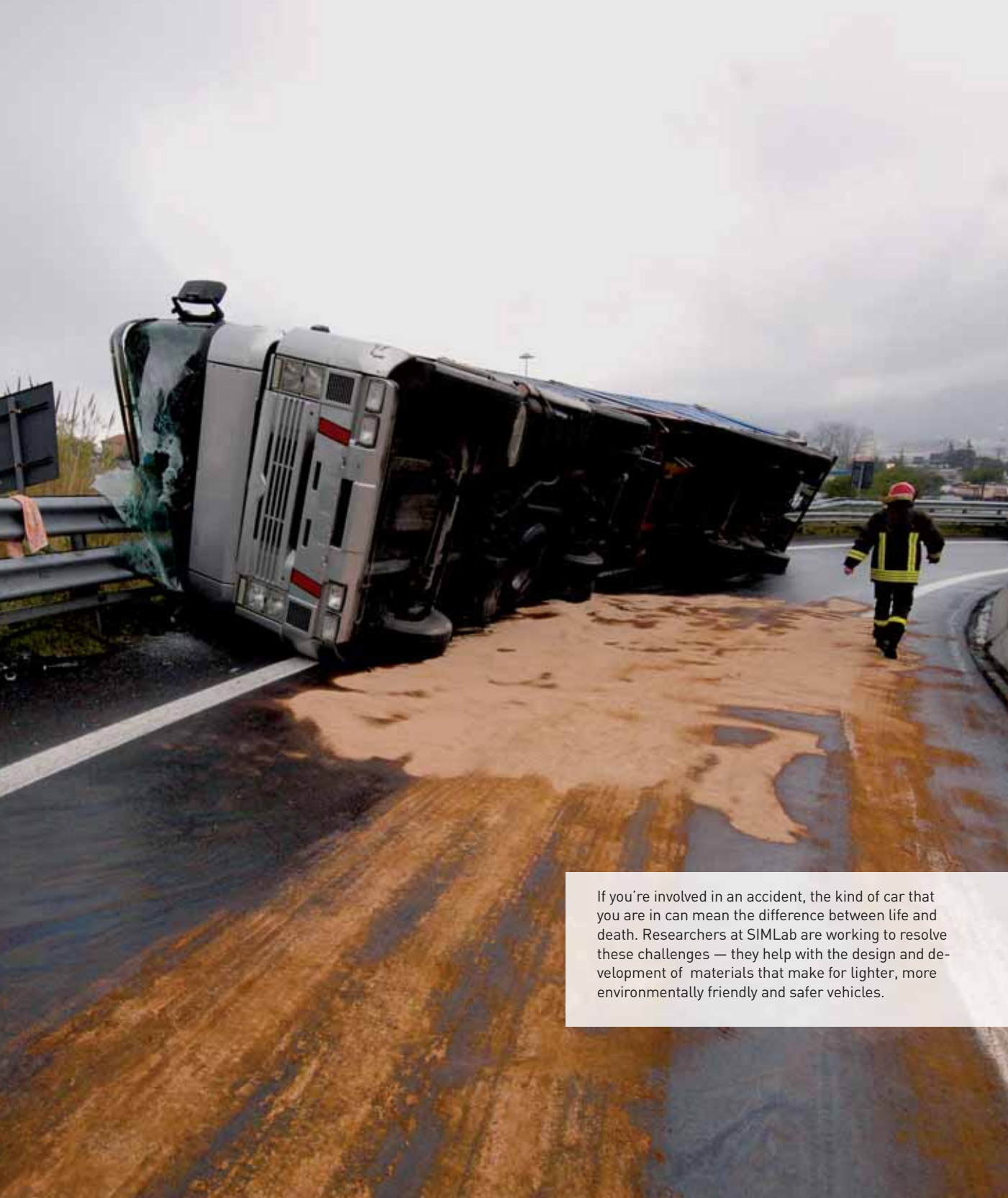
The Nordic countries were at the forefront of communications technology just when mobile telephony was being developed. Their systems were good, but they had a problem that made communications unstable: high-rise buildings, hills and other objects in the landscape tended to interfere with the signals.

SINTEF scientists Torleif Maseng and Odd Trandem had been puzzling over this seemingly impossible problem for some time. Now they were on the right track. Their new system was able to handle the reflections and radio interference that bounced off the steep high walls of a fjord. They had also tested their approach in the big city of Stockholm. The results were very good. It looked like their system was the best.

Paris, February, 1987

CEPT, the organization for all telecommunications companies in Europe, had arranged a convenient competition to select the new European standard for digital mobile telephony. Eight participants from five countries each rigged up a vehicle with high-tech equipment. While the competitors cruised the Paris streets, the equipment made continuous measurements of each system's transmission capacity and its ability to correct errors. The results were clear: The system that best handled the distortion that occurs when radio signals are reflected by topography and buildings was the Norwegian system, which was chosen to provide the basis for "Global System Mobile — GSM."

Today, the GSM system is the worldwide standard.



If you're involved in an accident, the kind of car that you are in can mean the difference between life and death. Researchers at SIMLab are working to resolve these challenges — they help with the design and development of materials that make for lighter, more environmentally friendly and safer vehicles.

CRASH DIET

Wars, car collisions, accidents: for most of us, this is the stuff of nightmares. For scientists at NTNU's Structural Impact Laboratory, or SIMLab, thinking about the worst that can happen — and how to protect us against it — is the stuff of everyday research.

One important aspect of SIMLab research is helping manufacturers put their cars on a crash diet — trimming kilos from their vehicles to make them more environmentally friendly without sacrificing performance or safety. Consumers want increased safety and more electronics — but they also want better fuel efficiency. Helping manufacturers reconcile those conflicting demands is where SIMLab researchers can make a difference.

And with roughly one billion cars worldwide — a number that is expected to double by 2030 as demand from China and India expands — building cars that meet safety standards as efficiently as possible is vital to the health of the planet.

SIMLab's efforts to develop numerical tools for the automotive industry to reduce weight without sacrificing safety are of great interest to the military, too. For instance, these numerical tools can be used to optimize lightweight protection systems for vehicles, or buildings that house military personnel and equipment in war zones.

Light metal magic

Norway may seem an unlikely place for aluminium research, but the history of this versatile light metal is nearly synonymous with Norway's own industrial history. Beginning at the turn of the 20th century, Norway was a new nation with few natural resources — except for hydropower. British investors brought capital to Norway to build aluminium smelters that could take advantage of the cheap, plentiful electricity that coursed out of Norwegian rivers and waterfalls. One hundred years later, the British investors are long gone, but their legacy is visible in Norway's cutting edge expertise in aluminium research.

SIMLab researchers carry on in this tradition, with sophisticated test laboratories and crash simulation programs that allow researchers to crush, drop, squeeze, explode, fire on, deform and otherwise destroy components and structures in a controlled way — so that they know where the weaknesses in light metals, polymers or steels are found, and why.

It's this kind of know-how that will help ensure that tomorrow's automobiles are greener than ever — by using aluminium, high-tech polymers or high-strength steels to cut a vehicle's weight. In addition to actual testing, SIMLab researchers have developed virtual tests that save time and money but still deliver results. One virtual simulation enables researchers use the information from one or two actual tests of a roadside guard rail to generate the equivalent of 50 different virtual tests.



This is what happens to the aluminium in your car when it is exposed to the kind of force that results from an automobile accident. By stretching, crushing and squeezing materials, SIMLab researchers can figure out exactly where the strengths and weaknesses in different automobile parts are found. The results help with the design of new components with improved properties.

100 INNOVATIVE YEARS



Cutting weight cuts emissions

Every 100 kg that is cut from a vehicle reduces CO₂ emissions by 10 grams per kilometre, and lowers fuel consumption by a half-litre per 100 km. These reductions per vehicle may not seem like much, but the sheer size of the world's automobile fleet means that every cut counts. Both Audi and Renault have benefited from SIMLab's results.

A DIVE INTO THE PAST

NTNU Museum of Natural History and Archaeology houses discoveries both large and small. The largest is perhaps the story of the world's most complex deepwater marine archaeological excavation.

Throughout the museum, you'll find world sensations, forgotten treasures and quirky laboratory equipment. The extensive natural and cultural history collections, thematic exhibitions and lush botanical gardens welcome 100,000 visitors each year. This is the place if you want to touch a moose, look into the brain, visit a Stone Age man, or stare into the ocean's depths.

Archaeologists in deep water

During a final check of the pipeline route to the Ormen Lange gas field on the Norwegian continental shelf, marine archaeologists at NTNU Museum of Natural History and Archaeology encountered something totally surprising. Their discovery led to a technological breakthrough for underwater archaeological research.

The story begins early in the 1800s:

A 40-metre-long wooden ship heels along the Norwegian coast on its way to Russia. The ship is fully loaded with wine and champagne, cognac and brandy, stacks of English plates and Chinese porcelain, German mineral water and Russian coins.

Out on the dark sea, something unexpected happens. The ship goes down.



The discovery of a number of archaeological treasures deeply buried in a ship at the bottom of the sea led to the development of new technologies and an underwater excavation of impressive dimensions. Today, the ship's contents have been brought safely to land, where they are now on exhibit at NTNU Museum of Natural History and Archaeology, where both young and old can experience marine history up close.

Fast forward to 2003:

Deep on the ocean floor off the central Norwegian coast lies the pipeline route for what will be the Ormen Lange gas field. This huge field is Norway's largest industrial project ever. But there are no surface installations at all — everything lies 800–1100 metres below the ocean's surface. Over the next 40 years, gas production from the field will provide 20 per cent of Britain's gas needs, along with serving other markets throughout Europe.

To ensure that the development does not affect possible archaeological finds on the seabed, marine archaeologists from the Museum of Natural History and Archaeology are hired to make a final check.

Treasures on the bottom of the sea

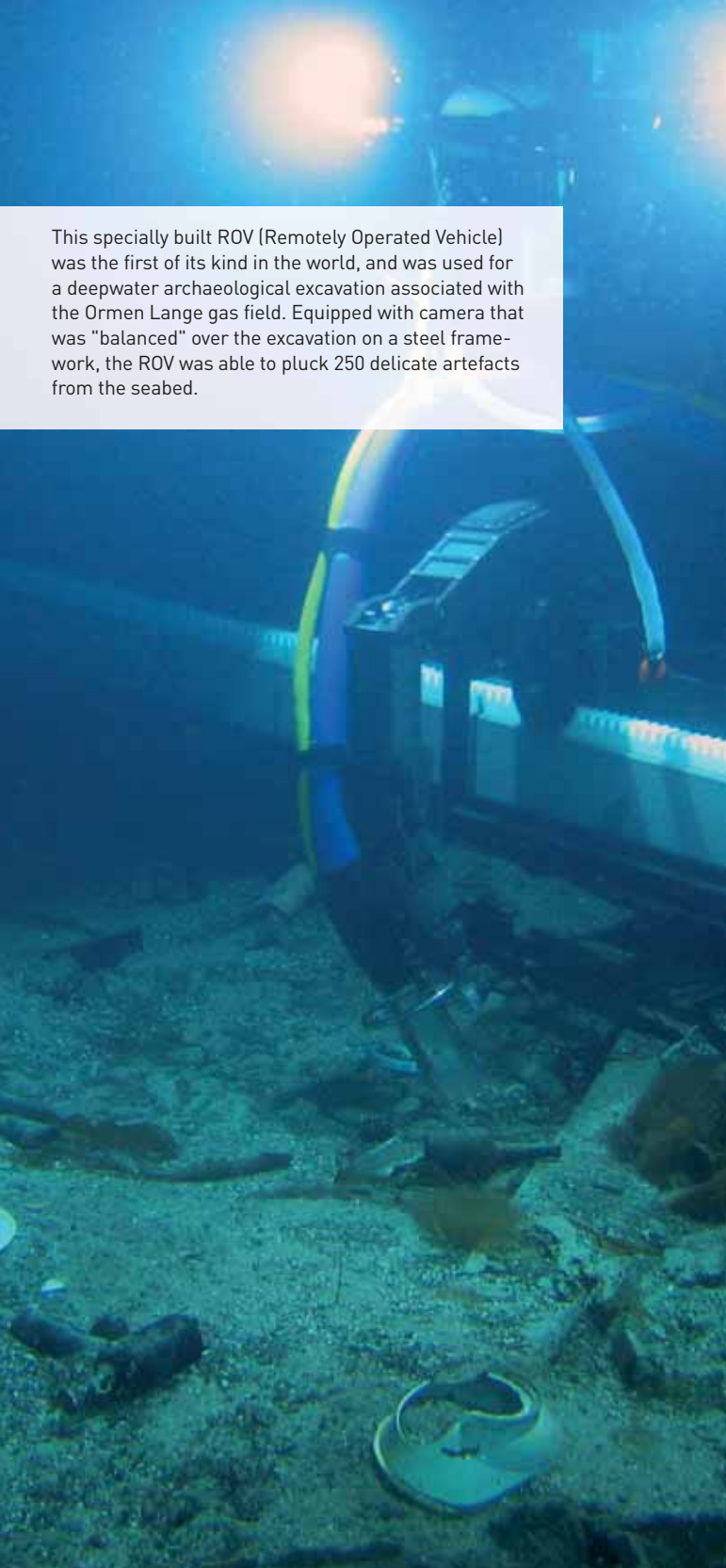
Between rusting steel hulls, fishing equipment, old refrigerators, oil drums, a wheelbarrow and a car from the 1950s, the archaeologists find something completely unforeseen: a 30- to 40-metre-long wooden structure, just barely visible on the seabed. Then they see wine bottles, porcelain and a ship's bell with the inscription "1745".

The team realizes they have made the archaeological equivalent of an oil strike. Their enthusiasm is great, but their worries are even greater: How can they document this discovery, collect research data and preserve historical artefacts from such depths? The archaeologists review what they know of underwater methods and vehicles, but don't find what they need to carry out such an operation. They need to think outside the box. It quickly becomes apparent that this challenge must be met with a whole new kind of technology.

A specially designed remote-controlled underwater craft was built and equipped with numerous sensors and tools. It can connect to an excavation frame that is positioned over the wreck. The craft uses gears to roll in any direction without damaging the precious artefacts below.

This meeting between traditional archaeological expertise and new technology made it possible to carry out the work with nearly the same precision as excavations on land. In all, 500 objects were brought to the surface. The excavation was completed in 2005.

NTNU's Museum staff is still studying everything that came up from the deep. The ship's identity remains unknown.



This specially built ROV (Remotely Operated Vehicle) was the first of its kind in the world, and was used for a deepwater archaeological excavation associated with the Ormen Lange gas field. Equipped with camera that was "balanced" over the excavation on a steel framework, the ROV was able to pluck 250 delicate artefacts from the seabed.

100 INNOVATIVE YEARS



First Environment Minister

The world's first environment minister came from Trondheim's academic community. Olav Gjærevoll was appointed Norway's first Environment Minister in 1972 — which also made him the world's first. His passion was the protection of biological diversity. Both before and after his appointment, Gjærevoll worked at NTNU Museum of Natural History and Archaeology, both as a researcher in the botany section and as the museum's director. He was also twice mayor of Trondheim.

Record land-based archaeological survey

Norway's most comprehensive land-based archaeological study was undertaken along with the underwater archaeological component of the Ormen Lange project. Bringing gas from the Ormen Lange field to the Norwegian mainland required the destruction of 34 cultural heritage sites. The archaeological dig and documentation were completed in record time, and resulted in the collection and categorization of 375 390 finds — some of them from as early as 9000 years before Christ.

Trondheim is a magnet for search engine research: Microsoft Enterprise Search, Sun Microsystems, Yahoo and Telenor have all established R&D departments in Trondheim to take advantage of the strong ICT community at NTNU.



FAST FINDINGS

Finding something in a messy garage can be a nightmare – unless you have a tool that can inventory everything and help you out.

To find things, you have to be good at looking. That's why it should be no surprise that the initiative behind one of the world's best online search services — FAST Search & Transfer Technology — came from an archaeologist.

The story first started in the 1970s, with two researchers at NTNU, each with their own area of expertise: Arne Halaas was a mathematician, Tor A. Ramstad worked with image compression. They both worked with the computer and electronics community at NTNU, with a group of specialists who had already begun to be busy with search technology. Otherwise, they had little in common.

One day they were both approached by archaeologist Hans Gude Gudesen. He had heard that the computer and electronics people were working with search technology, and hoped that they could solve his big challenge: to create a system that could quickly store and find information about a great number of complex archaeological objects.

Twenty years passed, and the interdisciplinary collaboration bore fruit. The NTNU computer community developed exceptional expertise in search technology, and several of its student projects were shared with the business community. Gudesen, Halaas and Ramstad's efforts evolved into a tool that could be used to search for anything on the Internet. In 1997, FAST Search and Transfer was founded.

FAST's www.alltheweb.com rapidly gained recognition as a quick and accurate web search service. Several major companies became interested and in 1999 the company signed an agreement with the Internet portal Lycos. In 2000, www.alltheweb.com was valued at \$6 billion, and the search engine was subsequently sold to the Internet giant Yahoo.

FAST Search & Transfer is currently owned by Microsoft and employs 1000 people in 25 countries.

LUXURY GOODS

More than 1.2 billion people worldwide lack clean drinking water.

The boy in the picture is one of the lucky world citizens with access to clean, plentiful water from the tap. As the world's population grows and the planet's climate changes, water will become an ever-scarcer resource. There is enough fresh water in the world for all, but much of it has been contaminated. Millions of people die every year because they lack water or because the only drinking water they have is polluted.

Raw sewage is an increasing problem in the megacities of the world, where 2.8 billion people have no access to proper toilets. This enormous unmet need is brewing a worldwide water crisis that many predict will lead to a new kind of conflict: water wars.

Purification, recycling and reuse of water are all ways to limit the coming water crisis. NTNU researchers are developing new techniques for water purification to provide clean, abundant water where and when it is needed.

Biofilm reactor

In 1987 Professor Hallvard Ødegaard at NTNU's Department of Hydraulic and Environmental Engineering received a call from a company called Kaldnes AS. The company wanted to develop a biological treatment process to remove organic matter and nitrogen from municipal and industrial wastewater. It turned out that Ødegaard was right man for the task. He came back with a technology called a Moving Bed Biofilm Reactor (MBBR).

This biological treatment method is very simple: Contaminated water flows




through a tank full of small plastic bits that are kept suspended by aeration. Micro-organisms (bacteria) grow on the plastic surface and use the nutrients and sewage in the water as "food". The oxygen that is introduced to the water from aeration then helps break the bacteria down into simple compounds. When the water is drained from the tank, a sieve keeps the plastic pieces and most of the bacteria in the tank, and any bacteria that escape with the water can be removed, so that only clean water is left.

Drinking water

Sewage water can be run through the system several times, enabling many different contaminants to be removed. As long as any stray bacteria are removed and the water is disinfected, it can be drunk after this treatment.

Today the MBBR technology is found in more than 600 sewage treatment plants in 50 countries across the globe. It is fast becoming the dominant biological purification method for wastewater from fish farming. Thousands of mini-plants based on this technology are also in use — 7000 are found in Germany alone. Because MBBR plants are cheap to operate and easy to deploy, they are also especially suitable for developing countries, where they are perhaps needed most.

The patent for this process is currently owned by Krüger Kaldnes AS, a company that is part of the Veolia Group, the world's largest environmental technology company. Inventor Hallvard Ødegaard is still the research head for water purification methods at NTNU. His focus today includes the development of membrane technologies for separating ions, molecules and particles from water.



Looks like pasta, but these small odd shapes are made of plastic, and are part of a water purification system developed at NTNU.

100 INNOVATIVE YEARS



The “NTNU concept”

can reduce water consumption in cities by 90 per cent.

Clean water is piped into a house and dirty water is piped out: This simple system is how most of the developed world handles its water and sewage today. But what if we purify and reuse water that is not that dirty?

You shower, cook, wash the car, water the lawn, brush your teeth. People in western countries consume an average of 200 litres of completely pure water a day. The “NTNU concept” can reduce this consumption to approximately 20 to 40 litres per day. The approach involves dividing the water into three different levels of quality: The best water is used for drinking, cooking and personal hygiene, the next best water is used for dishwashing, laundry and house cleaning, while the lowest quality water is reserved for use in the toilet, washing the car or watering the garden. The system includes a bioreactor to clean and recycle water (such as an MBBR) and separation reactors that could use membrane filtration as a cleansing technology.

TEACHING TOMORROW'S SCIENTISTS

These high school students have been given DNA samples from four people. As they undertake the challenge of isolating and analyzing the material, the identity of the criminal slowly becomes clear.

Welcome to the 21st century approach to teaching science. At NTNU's school laboratory, both students and teachers are encouraged to use unconventional approaches to learning — and teaching — science. Their efforts are being monitored by researchers who are looking for techniques that give students a better understanding of and interest in science.

Science literacy will be decisive in meeting future global climate and environmental challenges. The world needs more children and young people to be engaged by science — and to pursue science as a career. NTNU has a long history of developing innovative teaching approaches, demonstrated most recently by a project called Science Teacher Education Advances Methods (S-TEAM). Here, the focus is on science teachers and the methods they use to motivate children and teenagers. The idea is to look at the way science is taught now, to develop new methods that can motivate students.

S-TEAM is being conducted in classrooms all over Europe. Teachers have swapped their traditional approaches for interactive projects and assignments that really engage students' curiosity. While teachers and students test different projects, researchers are looking at how different national and cultural contexts affect activities in the classroom. The goal is to give students the opportunity to create and solve their own scientific puzzles, with the teacher as a guide.

The S-TEAM results are continuously shared among participants in an international forum composed of the project's 25 universities from 15 countries. One of the goals of the project is to see that its results are included in school curricula across Europe.



Science can be fun — and S-TEAM participating teachers are learning how to convey the joy of science by involving students with hands-on laboratory and real world projects. NTNU is the coordinating institution for S-TEAM, funded under the EU's 7th Framework Programme. This is the largest EU-funded project of its type.

NTNU's campuses house students, researchers and more than 100 laboratories.

Some of the facilities are situated in beautiful rural surroundings, others in urban areas.





All photos: Cathrine Dillner-Hagen

Except

P. 8–9: Jørn Adde
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P. 63: Sevan marine
P. 75: NTNU Museum of Natural History and Archaeology
P. 81: Arild Juul/NTNU Information Departement
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P. 84 bottom: DMF/NTNU Information Departement
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This is NTNU

The Norwegian University of Science and Technology (NTNU) is Norway's primary institution for educating the nation's future engineers and scientists. The university also has strong programmes in the social sciences, teacher education, the arts and humanities, medicine, architecture and fine art.

NTNU's cross-disciplinary research delivers creative innovations that have far-reaching social and economic impact.

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NTNU – 100 years in 2010

