TELL'US

SCIENCE IN NORWAY

DECEMBER 2001

NEWS FROM THE RESEARCH COUNCIL OF NORWAY

Bright, beautiful and medieval

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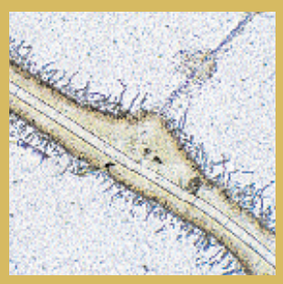

The rocky road from deep sea to deep space

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The Research Council of Norway

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Anne Tveit Winterthun/NIKU
Small pictures from top to bottom:
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The Research Council of Norway

The map shows the location of places referred to in this issue of Tell'Us

EDITORIALS

Apropos

Reporting on research and striving to ensure research-related topics a place on the public agenda are largely a question of consolidating the legitimacy and credibility of research. The mass media seem prone to focus on 'negatives', e.g. problems, disadvantages, scandals, etc. Things that work well are hardly considered newsworthy on an average day. But it is possible to make such items into headlines.

The Research Council is about to establish a National Committee for the Prevention of Scientific Dishonesty to promote and ensure honesty in research. Given the fact that the world has to deal with cloning, prion disease, nuclear power and other fields that engender considerable public scepticism, it was important for the Research Council to be able to reassure the general public that quality assurance is constant and pro-active when it comes to research.

Indeed, the new National Committee did make the headlines, and they were exactly as expected: "cheating in research". In other words, the fact that Norway had decided to establish a national committee for the prevention of scientific dishonesty was turned into a cheap shot, characterising researchers as capricious individuals who need to be monitored by a special committee. That was the price to be paid for drawing attention to the National Committee.

Of course, this might also be interpreted to mean that reporters can be rather capricious individuals of questionable moral integrity. Naturally, however, neither researchers nor reporters have more or less integrity than other people. Quality assurance and the efforts to promote ethical standards are a continuous process in both occupations. In this issue of Tell'Us, the reporters have been critical and creative in their presentations of researchers' hustle and bustle. Meanwhile, the researchers have also had an opportunity to check the quality of the reports about their specialities.

Together, they are dynamite, at least in our opinion ...

Mona Gravningen Rygh
Editor

The public's awareness of science

Can we increase the general public's awareness of science? If so, how?

These crucial questions are being explored by several European countries at the moment. In fact, this is the main topic of conferences almost every month. The EU Commission has put the topic high on its agenda, and many individual countries, whether they belong to the EU or not, are addressing the issue. The Research Council's "Research Week", special theme weeks and other activities are organised to try to give the general public insight into the world of research and researchers, and to demystify research. Nonetheless, the goal is still a long way off, inherent as it is in a far higher level of cognition and a far higher level of knowledge about research. It is important that the populace understands, and not least accepts, research as a building block, that is, a cornerstone of modern society.

What can a tiny country like Norway hope to accomplish? It is indeed a tiny country in the context of research, so we have identified a few fields in which Norway stands a chance of making worthwhile contributions to the international pool of knowledge. We are focusing our resources on those fields. The Storting (Norway's parliament) has selected 4 thematic target areas (marine research, medical and healthcare research, information and communications technology (ICT) and the interface between energy and the environment), as well as basic research, as the fields in which Norway will strive to excel in the years ahead. Over and above these fields, petroleum technology and biotechnology will obviously deserve special attention in the years ahead.

The articles in this publication focus on the above-mentioned target areas in particular, in addition to giving readers a glimpse or two of Norway's national cultural and social science research.

Those who master a Scandinavian language will find many more examples when our new website "forskning.no" goes online in early 2002. Initiatives such as this type of net-based information, in addition to publications like Tell'Us, are among the Research Council of Norway's ways of telling the world around us what we do, and how far Norwegian research has progressed. The website will not be exhaustive, but it is hoped that the brief teasers will give our readers a taste of what a tiny country like Norway can do when it targets its efforts on specific fields of research.

Happy reading!

Paal Alme
Executive Director
The Research Council of Norway

2000-year-old shipwreck found

At a depth of 60 metres in the waters off Ithaca in the Ionian Sea, Norwegian and Greek marine archaeologists have discovered a 2000-year-old shipwreck. It was carrying a cargo of several thousand amphoras from Roman times when it went down.

The find is a result of a large-scale search for cultural artefacts in Greek waters, using a remote-operated vehicle (ROV) and sonar equipment. Excitement ran high as the Norwegian ROV-designer Tor Olav Sperre remotely operated the ROV towards a mountain-like structure on the ocean floor and the cameras captured the first images of this fabulous find and the graceful lines of the amphoras.

The discovery of the shipwreck is a result of a pioneering co-operative venture between the Norwegian University of Science and Technology (NTNU) and the Greek Ministry of Culture. The venture was initiated at the request of the Greek Ministry of Culture, more specifically, the Greek Department of Underwater Antiquities, and is currently headed by Katerina Delaporta. The head of archaeological part of the NTNU group is Marek Jasinski of the Department of Archaeology and Cultural History, while the technical aspects are being headed by Norwegian Dr. Fredrik Søreide of the Department of Marine System Design. The project is thrilling, given Greece's rich cultural heritage and the classic Greek civilisation's pervasive influence on European cultural development. These waters are rife with cultural artefacts, but most of them have not been registered, least of all those in deepwater areas.

The project is scheduled to run for three years, and has already brought outstanding results. Several ancient wrecks have been located in the Aegean Sea and among the islands in the northern Sporades; and, in recent weeks, also between the islands of Cephalonia and the legendary Ithaca. The latter is well-known as the home of Ulysses, the hero who conceived of the idea to fill a Trojan horse with warriors, which eventually led to the fall of Troy.

The local waters are teeming with yachts, many named after the gods and heroes of antiquity. Holiday-makers amuse themselves along one of antiquity's busiest maritime routes to the Aegean Sea, the Black Sea and the eastern Mediterranean. The mainland and islands of Greece were provinces of the Roman Empire when the merchant vessel carrying the amphoras went down in the waters near Ithaca.

The wreck found by the scientists is believed to be from the Roman Era in ancient Greek history, making it some 2000 years old. Greek archaeologists have suggested this preliminary dating, based on the amphoras' shape, which often exhibits local, time-specific characteristics.

"The cargo appears exceptionally well preserved. This was a huge merchant vessel in its time, but its location made it inaccessible to amateur divers and it was not in the way of fishing gear", muses the Greek marine archaeologist Christos Agouridis contentedly.

Helge Sandvig

The Renaissance of the Old Maid

There are a myriad of myths about old maids. They are described and ridiculed as being plain, dried up, often bitter and definitely asexual. "Nothing could be further from the truth", comments the ethnologist Tone Hellesund of the University of Bergen.

Hellesund is researching the Old Maid phenomenon by taking a closer look at the lives of single women from 1900 to 1960-70.

"Single men and women are perceived very differently. While, in theory, single men are seen as bachelors and happy-go-lucky men about town, single women have far more often been called upon to defend their civil status from the compassion of do-gooders and the ridicule of others", observes Hellesund. She is of the opinion that this is because society created a stereotype of Old Maids a century ago when women who did not follow the well-trodden path to conjugal bliss had to make their own way in life, but had no well-defined role models to follow.

"The old maid represented the very epitome of Victorianism. She was moral, asexual and somehow noble. Many old maids found it most convenient to move about mainly in women's circles. There, they were able to cultivate their freedom and independence and, in many ways, they had the cultural latitude they needed to study and challenge the concept of femininity", explains Hellesund.

According to the researcher, female asexuality was legitimate and relatively generally accepted at the advent of the 20th century. However, that began to change in the 1920s and -30s, when asexuality was seen as unhealthy and abnormal. The male-female relationship changed drastically in the 1950s and -60s when the cultivation of homosociality became culturally unacceptable, and all attention was focused on the male-female dichotomy.

Hellesund believes the situation is different today. Even though it is more acceptable to be a single woman in certain circles, it is more difficult for modern women to "opt to be an old maid" than it was a century ago. Back then, the options were usually either to have children or a career. "Today, women are expected to have a career, but also to be a mistress and a successful mother", continues Hellesund. Choosing one option does not necessarily eliminate the other.

"Old maids have been mocked and derided, but it is important to bear in mind that being single afforded many of them a type of independence and an opportunity for self fulfilment through education and careers that few marriages could", concludes Hellesund.

Anita K.L. Thorolvsen

A rose by any other name is still a rose

Vastly disparate research traditions have resulted in different nations defining plant species differently and in varying ideas about the classification of plant species in the Arctic. A group of botanists from the northernmost countries of the world are now working together to agree on uniform definitions of species at the Centre for Advanced Studies (SHS). Their results will be compiled into a universal Arctic flora.

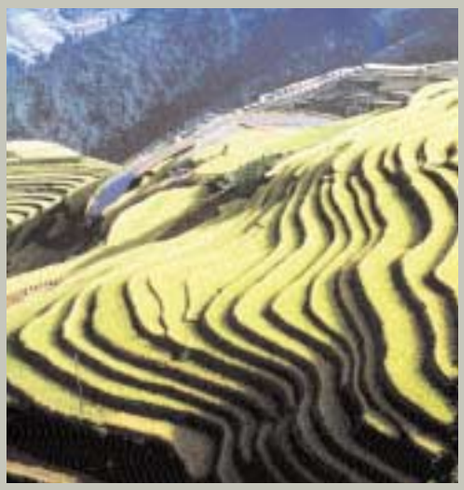
According to the SHS group's supervisors Reidar Elven and Inger Nordal, both professors of botany at the University of Oslo, this type of research was previously conducted behind closed doors, so different traditions evolved for classifying and naming species in the former Soviet Union, western Europe and North America.

"What makes the Arctic so special, is that the distribution of species is generally broader than in temperate zones. Another special feature is that there are virtually no insects in the Arctic, meaning the plants have to self-pollinate or clone to propagate. This constitutes an extreme form of inbreeding, which, by the way, is quite common in the plant kingdom. It has probably contributed to a great deal of variation between populations within the species", recounts Nordal. One example of this is a member of the rose family, the *Dryas octopetala*, commonly known as the dryad flower or mountain avens, which the group has chosen as its logo. Nordal is of the opinion that there is just one species of *Dryas octopetala* on Svalbard, while one of her Russian colleagues insists that there are three.

Ellen Stokland

BEAUTIFUL, BUT CONFUSING. The Dryas octopetala *is found in calcium-rich soil in mountainous areas of the far north. However, it is not clear whether Svalbard is home to one species of the plant or several. (Photo: Samfoto)*

Cereal polygamy



POTENTIAL: Scientists have developed a species of rice that contains more Vitamin A. Perhaps this rice can help save the vision of some of the 150 million children who lose their sight due to Vitamin A deficiency each year? (Photo: Scanpix)

The Norwegian geneticist Odd Arne Olsen is putting together cereal grains in new ways. He is convinced that genetically manipulated foods are vital if we are to feed more mouths.

Professor Olsen occupies a key international position when it comes to research on foods with enhanced nutritional content. "In 50 years, the world might have as many as four billion new mouths to feed. That fact is, in itself, a strong case for using gene technology to produce food", asserts Professor Olsen with great conviction.

Each year, 150 million children go blind due to vitamin A deficiency. Now a new breed of vitamin A fortified rice has been developed. Efforts are being made to make the rice available to interested countries. "This is just one example of the potential inherent in this technology if it is exploited prudently", states Olsen.

The professor heads research on genetically manipulated cereal grains at the US company Pioneer Hi-Bread/DuPont of Des Moines, Iowa, USA. As a geneticist at the Norwegian Agricultural University at Ås, Dr. Olsen was funded by the US company and the Research Council for five years as he sought to determine how genes govern plants. The research has attracted considerable international attention, not least because the path from basic research to practical applications is exceptionally short. "We are investigating the cereal endosperm, i.e. the starchy part used for food, animal feeds and industrial raw materials. This is humankind's most important source of energy. Using gene technology, we have managed to re-engineer cereals to increase their fat content, paving the way for enhancing their nutritional content", explains Olsen.

The plant physiologists at Ås are the first in the world to determine the cell fate of the endosperm. An endosperm has a simple biological structure consisting of just four cell types. The main aim of the researchers has been to monitor the formation of aleurone cells, as they are the ones that produce the fat content in cereals. Researchers recently managed to isolate the gene that controls the aleurone cells in corn. In actual practice, this means that it is possible, for example, to increase the oil content in corn by increasing the number of aleurone cells, and thus to get more oil out of each individual grain of corn.

Siw Ellen Jakobsen

▲ *CHURCH ON A VOLCANIC ISLAND: Although the replica of the Haltdalen Stave Church stands on a weather-beaten outpost at the approach to Heimaøy in the Vestmanna archipelago on Iceland, it is well protected from the raging wind and waves by a wall of hardened lava. To be on the safe side, a gallery was added to reinforce the outside perimeter of the church.*

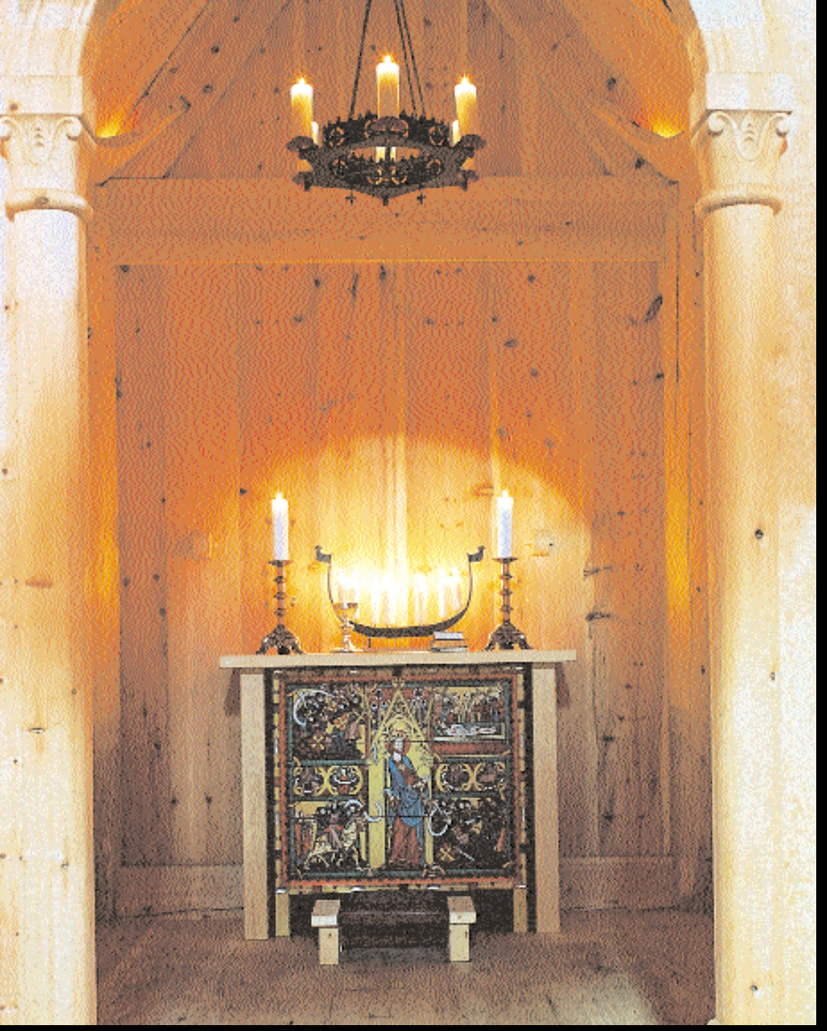
▶ *REPLICA: St. Olav Frontal from the Middle Ages (left), with its patina showing the ravages of time, and the colourful replica from 2000.*

Colourful middle ages

In collaboration with skilled artisans, Norwegian researchers have designed a replica of a Norwegian stave church and its altar ornamentation down to the finest detail. The work has added considerably to contemporary understanding of medieval building techniques and artisanship.

BY PAUL TORVIK NILSEN

PHOTOS: BIRGER LINDSTAD AND ANNE TVEIT WINTERTHUN, NORWEGIAN INSTITUTE FOR CULTURAL HERITAGE RESEARCH (NIKU)



A stave church now stands at the entrance to the harbour of the volcanic island of Heimaøy, in the Vestmanna archipelago. The building, a replica of the Haltdalen Stave Church in Trøndelag County, was a gift to Iceland from Norway in commemoration of the 1000th anniversary of Iceland's conversion to Christianity. The church has a spectacular location, situated against a wall of new lava from a volcanic eruption on Heimaøy in 1973 that buried large parts of the island.

The researchers and artisans who built the church knew from the outset that they were going to be re-creating a complex construction. Notwithstanding, they were surprised at how sophisticated the original actually proved to be. The reconstruction also disclosed that stave church interiors may have been ornamented in a striking array of colours.

One major task, in addition to building the church proper, was to reconstruct the St. Olav Frontal, one of the surviving examples of the works of art that decorated the front of the altars in many a stave church in the Middle Ages.

"The work on the stave church and altarpiece has helped refute some of our preconceived notions about the dark Middle Ages", remarks Elisabeth Seip, head of research at the Norwegian Institute for Cultural Heritage Research (NIKU) and supervisor of the replication of the stave church.

NATIONAL ROMANTICISM

People have only taken an interest in preserving and protecting the Norwegian stave churches for about the past 150 years. The painter J.C. Dahl was one of those who spearheaded the movement to instil a national awareness of the value of this aspect of Norway's cultural heritage.

"He personally helped ensure that the stave church at Vang in Valdres was salvaged and later re-erected in eastern Prussia, now part of Poland, where it still stands. The architects of the time subsequently studied Vang Stave Church, measuring the building and generating growing interest in conservation through their own personal commitment. Thus began the efforts to preserve these previous treasures that embody Norway's cultural heritage", continues Seip.

But how did the stave churches survive for more than 700 years prior to national romanticism? Although only a few of the once more than 1000 churches have survived to the present day, this type of building has shown remarkable durability.

"The stave churches are located in a country that had been on the periphery of Europe for hundreds of years. They were located a long way from the major cultural centres. The fact that they have been preserved is not mainly because Norwegians have been particularly concerned about preserving old things, but because the country was poor for long periods of time, so the people had to make do with what they had. Of at least equal importance is the fact that old Norwegian building customs were of excellent quality in terms of both materials and design. Consequently, the best of our building traditions have been retained, absorbing new styles from the Continent."

No new stave churches were built subsequent to the Black Plague, that is, after 1350. Nor was there any need for new buildings, since the population had been so drastically reduced. There were not enough people even to fill the houses of worship that already existed, and poverty can translate into good conservation. This was one of the main reasons why the stave churches were not torn down and replaced by new, less heavily ornamented church buildings.

UNIQUE ALTARPIECE

One key element in the stave churches, and a key to understanding religious life and everyday life in medieval Norway, involves the so-called frontals. Researchers are currently aware of the existence of 29 frontals or fragments of frontals. These ornaments do not rest on the altar proper, but in front of the altar. The best-known is the St. Olav Frontal, made in the High Middle Ages, probably in about 1320.

A reconstruction of this work of art was made for the newly erected replica of the Haltdalen Stave Church. The reconstruction shows how the original may have looked when first created in the Middle Ages.

"The result is sensational. The St. Olav Frontal was a rainbow of bright colours. Contrary to the original's repressed expression, ascribable to natural ageing, the reconstruction is distinguished by intense colouring. The powerful coloration and the lively depictions must have brightened up a semi-dark church interior and had a strong impact on the people who lived back then", explains conservator Terje Norsted of NIKU. He headed the work aimed at teasing the secrets out of the old wooden altarpiece.

The painting was grounded on a layer of chalk mixed with animal glue. The motifs were drawn on the grounding before the painting began, as was done on the original frontal. To make the reconstruction, researchers had to make their own paints, just as the original artisans did in the Middle Ages. "We used the same pigments as in the original. Many of the colours had not been used for ages", Norsted points out.

EXCELLENT ARTISANS

The forerunners of the stave churches were pole churches, made with poles buried straight into the ground to provide the requisite stability. Under several of the stave churches still standing today, researchers have found holes that bear witness to the fact that there were once poles there to support earlier churches that had stood on the same site, but the substructures have rotted away. In stave churches, the wooden construction is lifted off the ground and onto stone foundations, significantly increasing the life span of the buildings.

Throughout this project, researchers from many disciplines made in-depth studies of artefacts from the Middle Ages in Norway. Botanists, archaeologists, architects, conservators and historians all contributed.

Yet without the skilled artisans who have safeguarded the old traditions of building in wood, the project would never have been possible. The materials for the 'new-old' church were brought from Røros and construction took place in the highland village of Lom, an area in which such traditions remain strong.

"The artisans have worked in fields that our forefathers managed to elevate from artisanship to art. During planning and reconstruction, we constantly had to ask ourselves how the individual details and elements could best be constructed. In many places, Norway's climate has been favourable for the preservation of wooden buildings, and the stave churches were built of materials and with methods that made the buildings the contemporary art of the times. They were the best of the best. That is why the churches are still standing. The construction methods represented state-of-the-art technology back then", reports Seip.

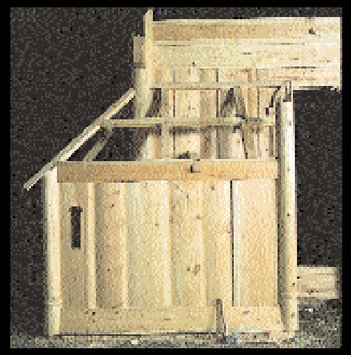
KEEPING SECRETS

These tiny wooden churches from medieval times are especially interesting because they have yet to disclose many of their medieval secrets.

"The stave church inspired the production of new knowledge. With the Haltdalen Stave Church, we have made extensive investigations to allow us to understand and protect more of this European building heritage. This work has taught us a bit more about the efforts involved in erecting these buildings, allowing us to solve a new piece in this particular puzzle of cultural history.

◀ *COLOURFUL: It may be no more than a myth, but there are indications that the well-preserved St. Olav Frontal from approximately 1320 may have been located in the Haltdalen Stave Church. Accordingly, a copy of the restored frontal was made for the new church on Iceland.*

◀ *PRECISION: Precision was a must every step of the way. The baptismal font was squeezed into the church.*



◀ *COMPLEX DESIGN: Researchers, architects and artisans quickly realised how sophisticated the stave churches' designs are, meaning that recreating the original was no mean feat. Motif from the construction at Lom.*

▶ *READY FOR THE CONSECRATION: "All of Norway" was behind the project: Logs from Røros, shingles from Odalen, tar from Skjåk, wrought iron from Vågå, doorstep from Holtålen, built in Lom – the list goes on and on.*

▲ *A DETAIL: Hand-cut, tarred shingles of the finest quality are required to stand up to the rain and wind on the Vestmanna Islands.*

▲ *NEARLY 900 YEARS OLD: Urnes Stave Church in Luster in Sogn, dated to the 1130s, is one of the country's oldest and most precious cultural treasures from the Middle Ages. It is on Unesco's World Heritage List, where one of criteria is the preservation of the monument's original characteristics.*

▲ *HALTDALEN STAVE CHURCH: The original building is at the Trøndelag Cultural Heritage Museum in Trondheim.*

CONSECRATION: The residents of Heimaøy thronged to the consecration of the stave church.

Stave church to Iceland

"The Norwegian people's gift to Iceland" was a stave church for the Land of the Sagas, to commemorate the 1000th anniversary of Iceland's conversion to Christianity. The gift is a replica of the Haltdalen Stave Church, now located at the Trøndelag Cultural Heritage Museum in Trondheim.

The project, including preliminary investigations, research and building, began in 1998 and took three years. The church was consecrated on the Vestmanna Islands in the summer of 2000. The Storting (Norway's parliament), allocated MNOK 5.5 for the project.

Plumbing the depths

CORROSION. Researchers Jon Kvarekvål (l.) and Egil Gulbrandsen have produced new knowledge about how to inhibit corrosion in oil and gas pipelines.
(Photo: Bjarne Røsjø)

As oil and gas production moves to greater ocean depths, the Norwegian oil industry will be remotely controlling the process from land. The industry is currently devising technology hitherto unseen in the world, and it will change the face of coastal Norway.

BY BJARNE RØSJØ

The Norwegian oil industry plans to produce oil and gas at ever greater depths using compact, intelligent drilling and production units designed to stand on the ocean bed and be remotely controlled from land. This new technology will change the face of coastal Norway, and may even signal a new era of global technological progress.

THINKING NEW

The most visible result of producing oil and gas at great ocean depths is that the leviathan oil platforms that have dominated the North Sea for the past 30 years will disappear. But the most important result, on the other hand, is that subsea development will generate a huge volume of new knowledge and technology. Norway's petroleum research communities have already come a long way in this process.

"Political aspirations regarding reducing emissions of greenhouse gases, as well as the oil industry's focus on production at ever greater depths and from smaller, less accessible reservoirs, call for new types of production facilities and better means of transportation", comments Product Manager Morten Dalsmo of ABB AS, part of the international technology corporation, the ABB Group. Dalsmo is facing the new chal-

THE DINOSAURS OF THE NORTH SEA: The gigantic oil and gas platforms are on their way to extinction, giving way to new, more compact subsea production solutions.
(Photo: Husmo/megapix.no)

◀ *TRANSFORMER SANS SEMI-CONDUCTORS. Espen Haugs (l.) and Frank Strand of Magtech AS testing an early demo system. Computer technology is not suitable for the ocean bottom, so the enterprise has designed a frequency converter without semi-conductors. (Photo: Bjarne Røsjø)*

◀◀ *FAST-TRACK CORROSION This picture shows CO_2 corrosion. Corrosion on the inside of pipelines can occur exceptionally quickly if not inhibited somehow, and the deposits can eat through a pipeline wall in just a few years. (Photo: Institute for Energy Technology)*

lenges by establishing broad-based collaboration with the oil company Norsk Hydro and five departments at the Norwegian University of Science and Technology (NTNU). The partners are absorbed in developing a new discipline, petronics, with financial support from the Research Council of Norway.

"Petronics is a new, interdisciplinary discipline in the global context. The project is being used to create new links between disciplines. This is absolutely essential if we are going to solve the problems we face when producing oil and gas at great ocean depths. Petronics involves linking together knowledge from petroleum technology, multi-phase technology, engineering cybernetics and systems technology", continues Dalsmo.

COMPUTER CRUNCHING

The recently established enterprise Magtech AS is facing another of the challenges posed by extreme ocean depths: Computers and other equipment are reliant on semi-conductors (substances that conduct electricity better than insulators, but more poorly than conductors). The best-known semi-conductors are germanium and silicon, but they are not suitable for placement at great ocean depths. A glass-like material, silicon would quite simply be crushed if subjected to excessive pressure. Consequently, it is not possible to use computers or other semi-conductor equipment on the ocean bottom without encapsulating them in compression tanks. However, at depths of 3000 to 4000 metres, the pressure is so strong that the tanks would have to weigh as much as 50-60 tonnes more than the equipment they are intended to protect.

"The oil companies need huge pump motors that can be placed on the ocean bed. Modern-day motors for such purposes can only be controlled using frequency converters and they depend on semi-conductor technology. To solve the problem, we designed a frequency converter that can be controlled magnetically", reports Managing Director Espen Haugs of Magtech. The design has already created quite a sensation, not least because it can also be used to reduce the power losses suffered in connection with terrestrial transmission of electrical energy.

THE OIL AGE IS STILL GOING STRONG

Magtech is a prime example of how technological development in one industry can have a major impact on other sectors. "By continuing and expanding our efforts to exploit the tremendous potential inherent in petroleum activities, we will also promote the development of other industries such as the IT industry", states Jan-Erik Nordtvedt, Chairman of the Board in the research programme, Petroforsk.

"The oil and gas industry will offer plenty of opportunities for adding value for many years to come. There are several reasons for this. First, we have only recovered about 20 per cent of the known petroleum resources, and second, the opportunities for technological development in the North Sea can be exploited much more effectively in future", he adds.

Nordtvedt's hobby horse is that both the oil industry and Norwegian suppliers must see themselves as global players to a far greater extent. "Technology enterprises can generate new exports for themselves and for the oil companies if we focus more on making them into global knowledge enterprises. Thus far, Norwegian technology enterprises have piggybacked on the oil companies to venture out into the world, but the technology enterprises have a tremendous potential as independent door openers", asserts Nordtvedt.

A LOCOMOTIVE FOR OTHERS

Also Information Director Maiken Ims of the Norwegian Oil Industry Association is convinced that the Norwegian petroleum industry stands poised on the threshold of a new and fascinating future. "In actual practice, the oil industry is Norway's largest IT industry when it comes to applications. The industry inevitably uses the latest and best technology available in all fields of technology. There are great opportunities for knock-on effects through innovation and spin-offs. No other industry in Norway has the same ability to bring about knock-on effects simply by requesting knowledge, research and expertise from related industries", she observes.

The Institute for Energy Technology (IFE) at Kjeller outside Oslo is part of this new development. Iron, steel and saltwater do not mix well, and IFE has invested considerable research efforts in reducing corrosion in the pipelines used to transport oil and gas in the North Sea. This new knowledge already saves the oil companies many millions of Norwegian kroner each year. A prime example is the Troll field, where the pipelines to the processing facility on land actually suffered very little corrosion. "But a tiny bit of corrosion goes a long way! In a 70-km long pipeline, it turned out to be a huge problem since no less than 70 kg of dissolved iron reached the processing facility every single day. The iron was the source of untenable operational disruptions and maintenance problems", reports Senior Researcher Egil Gulbrandsen at IFE.

TAMING CORROSION

In 2000, Gulbrandsen and his colleague Jon Kvarekvål completed a research project designed to study which factors are most important when it comes to enhancing the effect of the anti-corrosives used in the pipelines. Kvarekvål explains that IFE had two main objectives for the project. "The one was to determine which factors are critical for anti-corrosives, and the other was to develop testing methods to help the oil companies make more informed choices of anti-corrosives for each individual pipeline", he explains.

"The project has shown that the content of solid particles in the transported matter plays an important part, and this was a completely new discovery. The oil and gas streams also contain water and some solid particles of substances such as sand, clay and limestone. These solids can often be finely distributed, meaning they have a large surface area. We found that the anti-corrosives largely work by attaching themselves to these surfaces, reducing the particles' effect on the surface of the pipelines", continues Gulbrandsen.

The problems with the iron deposits in the Troll pipeline were ultimately solved by adding caustic soda. "The Elf oil company came up with the idea of adding organic bases to increase the pH value of the wellstream. But the bases were hazardous for the environment, so we experimented with other substances instead. Finally, we ascertained that common caustic soda was well suited for the job, reducing corrosion by no less than 90 to 95 per cent. The operator, Statoil, reports that they saved several hundred million NOK by solving the the problem that way", smiles Gulbrandsen.

Powerful oil companies make different choices

The oil companies Shell and ExxonMobil are approximately equally international and powerful, but they pursue vastly different climate strategies.

The most important reason for this difference appears to be different political conditions in the oil companies' home countries. The oil companies are influenced by disparate economic and political assessments, according to researchers Tora Skodvin and Jon Birger Skjærseth.

MORE POWERFUL THAN NATION STATES

"Many people take it for granted that global players in same industry have similar interests. Our survey indicates, however, that similar companies with tremendous power have opted to pursue diametrically opposed strategies. It is extremely important to study these gigantic multi-nationals and find out why such differences exist, since such companies can wield considerably more power than many nation states", remarks Tora Skodvin of the Cicero Center for International Climate and Environmental Research, as Jon Birger Skjærseth of the Fridtjof Nansen Institute nods his agreement.

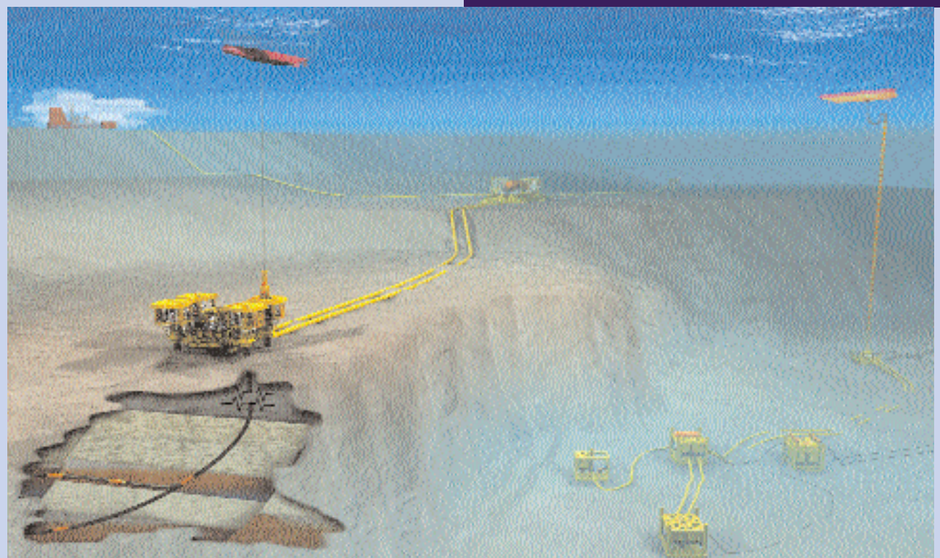
In the international climate debate, ExxonMobil carved out a reputation as an important source of support for US President George W. Bush in his struggle against the Kyoto agreement, while competitor Shell takes a friendly view of renewable energy and has got rid of its entire coal division.

POLITICS AT THE ROOT OF IT

"There is a tremendous difference in how Shell and ExxonMobil would like to be perceived, even though their operations are relatively similar. Initially, we postulated two different types of explanations: Either the companies are quite simply very different, or the differences stemmed from the political context within which each company op-erates. We found, rather surprisingly, that it is the political context that best explains the differences", states Skjærseth.

"Shell is a British-Netherlands company that supports the Kyoto Protocol, largely because the company's management is sensitive to pressure from the European authorities and public opinion. By way of comparison, ExxonMobil, the world's largest oil company and the world's most profitable company to boot, is American and has been strongly involved in the Global Climate Coalition (GCC) that represents a broad cross-section of American business interests that are fighting against the Kyoto agreement. GCC won a major victory when George W. Bush was elected president of the US", observes Skodvin.

DIAMETRICALLY OPPOSED. Environmental researchers Tora Skodvin and Jon Birger Skjærseth have sought an explanation for why the oil companies Shell and ExxonMobil have adopted such different strategies on climate issues. (Photo: Bjarne Røsjø)



SUBSEA TO BEACH: Tomorrows technology will allow seabed processing and separation of gas and oil, and transportation by pipelines to onshore plants. Subsea production facilities and pipelines to transport wellstreams to land will reduce CO_2 emissions. (Drawing: DEMO 2000)

The quest for bio-gold

Norwegian researchers are on a quest for new substances that kill bacteria, inhibit virus and fungus and regulate cell growth. They are finding them in simple, primordial organisms both on land and at sea, as well as by screening synthetic compounds that mimic natural substances. These compounds seem to be especially abundant in the icy cold waters of the Arctic. This discovery could have a major impact on the food and medicine industries.

BY SIW ELLEN JAKOBSEN,
PAUL TORVIK NILSEN AND BJARNE RØSJØ

LIQUID GOLD: The contents of this bottle were extracted from 4000 litres of thaw water from shrimp, leaving a biochemical worth NOK 1 million per gram. (Photo: Biotec)

Nearly 200 years have passed since the Norwegian marine biologist Michael Sars discovered the presence of living organisms at ocean depths greater than what was commonly believed possible in the early 1800s.

There are still several million unidentified organisms in the ocean, waiting to be scientifically described, understood and exploited.

Valuable substances are found in nearly all marine life, from algae and invertebrates to crustaceans, fish and mammals. Anti-bacterial substances (antibiotics) have been found in molluscs, toad crabs, Northern pink shrimp, hermit crabs, king crabs, sea urchins and starfish, as well as in kelp and seaweed.

Gene research, biotechnology and bioinformatics can be used to enhance genetic characteristics, and to search for useful 'new' molecules, genes and enzymes in micro-organisms. The latter is called bio-prospecting. Analogous to the word prospecting in its traditional sense, bio-prospecting is the search for biological gold.

BREAKING NEW GROUND

The ocean is home to species ranging from those that live in sub-zero temperatures to others that tempt fate in habitats with temperatures that exceed the boiling point. The oceans contain aerobic and anaerobic species, species that require high and low salinity levels, and species that require very little or extremely much light. In other words, the oceans contain the full range of organisms, including species balanced on the extreme edge of existence.

The waters off the Norwegian coast, particularly in the Arctic, are considered a genetic gold mine, and may prove to be even more important than the rain forests.

"Organisms adapted to cold water have unique characteristics, and Arctic waters contain a wide range of such little-studied organisms", comments Trond Jørgensen, professor of biotechnology at the Norwegian College of Fisheries Science in Tromsø,

Photo: Windfish/organic.no

Photo: Samfoto

Photo: Wradh/megapix.no

a Norwegian pioneer in the field of modern marine bio-prospecting.

"First, researchers examine molecules, genes and others mechanisms in the cells. Then they purify and culture them, re-arranging DNA into new combinations and habitats in bacteria cultures, for example. This allows us to observe the processes that are initiated, and tell whether they involve biological specialities that can be studied and exploited.

"Simple marine organisms lack immune systems with white blood cells. Nonetheless, they produce anti-bacterial substances, or more correctly, antibiotic molecules, in response to infections. Finding out how they manage to do this is of great importance. Yet we have barely begun to understand even a tiny part of the complex biological processes, and we are moving through previously unexplored territory", Jørgensen emphasises.

"Eventually, we hope to be able to tailor molecules to particular objectives. This is now possible because we can identify the entire DNA genome (see box) in a cell. Once we have mapped the genome, we can make identical new cells, or molecules in a cell, allowing us to produce artificial biochemicals in laboratories", says Jørgensen.

A CHILLING IDEA

A prime example is the enzyme contained in the water left when we thaw shrimp. The Tromsø-based enterprise Biotec ASA sells an enzyme extracted from the water left from thawing frozen shrimp for NOK 1 million per gram on the world market. According to Biotec, this is without a doubt the highest (per unit) priced Norwegian export product currently on the market.

The water left from thawing contains tiny amounts of the sought-after enzyme. Following a week of constant processing, 4000 litres of water left from thawing are reduced to about 40 litres of concentrate, from which pure enzyme is extracted in an adjacent laboratory. In other words, it takes 4000 litres of water to make less than one gram of the enzyme, which is an ultrapure "bio-catalyst" for biochemical processes. The product's strongest selling point is that it consists of an enzyme that is adapted to the cold, since the shrimp live in Arctic waters. Enzymes adapted to the cold are easier to render inactive by applying heat, an advantage for those who will be using the enzyme.

The enzyme is useful for researchers and laboratories engaged in DNA-sequencing, molecular biology research, and diagnostics, including the mapping of genes and forensic medicine.

However, fisheries by-products are not enough to constitute an industry. The genes for the substances Biotec is looking for have also been isolated, facilitating production of the substances by genetic engineering.

"If we isolate the gene that codes the enzyme, we can implant it into a micro-organism. Once that is done, the micro-organism will produce more enzyme whenever we want", says head of Biotec's research department, Dag-Rune Gjellesvik.

▼ *VACCINE: A research project in Bergen can lead to the development of edible vaccine, which would be a major step forward. (Photo: Samfoto)*

HOLY COW?

Yet another example: The pharmaceutical industry makes capsules for pills out of pigskin or the sinews and bones of cattle. A group of researchers at the Norwegian University of Science and Technology (NTNU) in Trondheim claims these cap-sules can be made of fish gelatine, possibly in combination with another marine biopolymer (see explanation in the fact box).

"I frequently receive queries from businesses in the US that are interested in the status of this research in Norway", reports Olav Smidsrød, a professor of biopolymer chemistry and head of the Norwegian Biopolymer Laboratory (NOBIPOL) at NTNU. It used to be considered impossible to make capsules of fish gelatine because its melting point was too low.

"We are trying to exploit synergies with other gel-forming marine biopolymers (see box) or to add enzymes that can upgrade the gelatine and imbue it with the right properties", continues Smidsrød.

NOBIPOL's research has long been closely associated with industry. Professor Smidsrød attributes much of NOBIPOL's success to this co-operation.

PROMISING HIV MEDICINE

Based on a group of scientists under the command of Professor Kjetil Taskén at the Department of Medical Biochemistry at the University of Oslo, the enterprise Lauras a.s. has entered the race to develop an effective drug to combat HIV and AIDS. All today's drugs are designed to attack the virus *per se*. Lauras is trying to find ways to strengthen the body-'s immune system, allowing the body itself to fight the deadly virus.

HIV-infected patients have an elevated level of the signal substance cyclic AMP (adenosine monophosphate) in the type of white blood cells known as T-cells. This substance tells T-cells when to turn down the immune response, making the cells less able to attack viruses and bacteria. An elevated level of cAMP leads to the production of more HIV virus. Thus begins a vicious circle. Lauras' idea is to break the vicious circle by adding a chemical compound that prevents the production of excessive amounts of cAMP.

TAILOR-MADE DNA

In future, specially designed DNA molecules will be used to treat and prevent diseases. Thus far, it has been difficult to introduce DNA into the cells of the body effectively. Now, the biotechnology company Inovio as of Oslo has patented a technique that can help solve the problem.

In future, DNA therapy can be used as a vaccine, not merely against HIV, but also, for example, against malaria, and for new treatments for cancer and a number of diseases ascribable to the body's failure to produce important hormones or other proteins by normal means. The US patent authorities have granted Inovio's application to patent a method to introduce DNA molecules into body cells using electrical simulation (electrophoresis). Inovio as has *inter alia* tried to inject DNA from tuberculosis bacilli.

The muscle fibres absorbed the DNA and began to produce a protein normally produced by tuberculosis bacilli. In turn, the protein triggered an immune reaction in the mice. This indicates that the method can be further developed into a new type of vaccination against tuberculosis, according to the two founders, Professor Terje Lømo and Dr. philos. Iacob Mathiesen, of the Department of Basic Medical Sciences at the University of Oslo.

"Provided we prove the technique can be used against tuberculosis, for which there is no genuinely good vaccine today, it can probably also be used to make other DNA vaccines", states Mathiesen.

The patented electrophoresis technique is based on introducing a simple DNA plasmid (a ring-shaped molecule) into a cell using electrical simulation. A competing method involves introducing DNA into a cell using a virus, but the method is fraught with considerable disadvantages and hazards.

HOCUS POCUS: By concentrating the thaw water from shrimp and passing it through such columns, it is possible to "wash away" extraneous proteins, purifying the enzyme. Performed in several steps, this enhances the purity of the enzyme from 0.1% to 100%. (Photo: Biotec)

Edible vaccine

Researchers are in the process of identifying all the genes in a bacterium that can live on methane and make proteins that can be used for animal and fish feed. Now they believe the bacterium can also be used for vaccine. Professor Johan Lillehaug of the Department of Molecular Biology at the University of Bergen heads the research project. "First we are mapping the entire genome of the bacterium, known as M. capsulatus. After that, we will learn more about how the genes can be exploited and which characteristics they are coded for.

The bacterium is already under production. The enterprise Norferm DA's factory on Tjeldbergodden will be "fed" methane from an oil field in the North Sea. The produced bacteria are a rich source of proteins that can be added to fish and animal feed and it is guaranteed free of infection.

Lillehaug believes the bacterium will probably lend itself to numerous other interesting applications. It is completely innocuous and can be eaten by animals and human beings alike. Consequently, researchers maintain that it should be possible to use the bacterium for edible vaccines, especially in the fish-farming and agricultural industries. In the long run, human vaccines should also be feasible. Getting vaccines into edible capsules would be a huge step forward, especially in the Third World where tropical heat and dirty needles are major obstacles for vaccination programmes.

"To make an oral vaccine, we must alter the bacterium so that it makes an antigen on the outside of it. An antigen is a molecule that stimulates the production of antibodies. The bacterium can then be dried and added to feeds. Animals that eat this feed will be exposed to the antigen and react by making antibodies. This way, the antigen-carrying bacteria will act as a vaccine", explains Lillehaug.

The researchers in Bergen co-operate with the Institute for Genomic Research (TIGR) on the mapping of the bacterium's genes. The Americans found this work so interesting that it only took them three weeks to get the US Department of Energy to allocated USD 1 million to the project. The director of TIGR, Claire Fraser, who, by the way, was awarded an honorary doctorate by the University of Bergen last year, remarked in an interview that the professional co-operation she and her colleagues at TIGR have with the Department of Molecular Biology, is one of the most fruitful relationships they have ever had.

Life in the pre-Viking landscape

IRON AGE FARM: Outside Stavanger you can visit this farm, built on the spot where archaeologists have found remnants of houses from the Iron Age. (Photo: Museum of Archaeology, Stavanger)

Photo: Samfoto

"Iron Age Norsemen lived in an agrarian society where people cultivated barley to make porridge, bake flatbread and brew beer, and they grew flax to make linen for clothes. The farmers probably had thralls, that is, bonded servants. Women generally bore their first babies at the age of 14 or 15, and few people lived past the age of 40," explains Ole Grimsrud.

BY BÅRD AMUNDSEN

Archaeologist Ole Grimsrud of the Department of Archaeology at the University of Oslo provides us with a glimpse into the everyday lives of Norsemen some 2000 years ago, about 800 years before infamous hordes of Vikings descended on Great Britain, Ireland and France. Seemingly appearing out of nowhere, the Vikings quickly carved out a most violent place for themselves in European history. Yet the Vikings too had predecessors. Norwegian and Nordic archaeologists are now learning more about the people who lived in the high north prior to the Viking Era.

Thanks not least to the Icelandic saga writer Snorre, we know quite a bit about the Vikings of Norway, including the names of their rulers and how they lived. That being said, the history of Norway in pre-Viking times was largely a blank until recently.

A SMALL VILLAGE

Iron Age Norsemen lived on the periphery of the Roman Empire, which also put them on the periphery of the major waves of European migration. Recent archaeological digs and, not least, new research techniques have resulted in the unearthing of a steady stream of knowledge about who these people of the north, the Norsemen, really were.

For several thousand years after the Ice Age, the topography along the east side of the Oslo Fjord and further south along the Swedish coast consisted of beautiful skerries and islands, offering Stone Age Scandinavians protection from the weather as well as an abundance of food from land and sea. By the time iron, and thereby the Iron Age, reached the people here roughly 2500 years ago, the ground had risen significantly, transforming the island landscape into rolling ridges and fertile plains.

Three years ago, the Ås Municipal Council decided to build new senior citizen housing on a gentle hillside overlooking the local farmlands. It was here, on the south side of one of the major moraine ridges, where a number of historical discoveries had been made, that archaeologists had to make investigations before construction equipment was allowed on site.

It came as no great surprise when several finds were made almost immediately. Over the three past summers, archaeologists have excavated jewellery, ceramics and traces of 18 houses. Most of the finds can be dated back to between 0 and 400 AD, but the area has also revealed traces from the Norwegian Bronze Age (1700 to 500 BC)

IRON AGE FARM

In the summer of 2000, head of the digs, Ole Grimsrud and his colleagues found three longhouses of the type commonly found around the entire North Sea back in those days. The longhouses were often shared, with cows and sheep occupying one end and people living on the other. The walls of the houses consisted of birch saplings, closely woven, then stuffed with clay for insulation. The roofs were held up by columns and probably covered with turf.

The people on this farm may have been relative-

TREASURES: Iron Age jewellery found in Norway bears witness to a rich, very characteristic Nordic ornamentation. (Drawing: C. F. Lindberg, from the book "Norske Oldsager" ("Norse Antiquities"), Oluf Rygh, Tapir Forlag Christiania, 1885).

◄ *JEWELLERY: This is a buckle of gilded silver from the Early Iron Age (0-500 AD). (Drawing: C. F. Lindberg, from the book "Norske Oldsager" ("Norse Antiquities"), Oluf Rygh, Tapir Forlag Christiania, 1885).*

IRON AGE COOKING: Archaeologist Ole Grimsrud beside two large, exceptionally well preserved cooking pits located side by side. Only half the holes have been excavated in order to reveal a cross-section. (Photo: Cato Guhnfeldt/Scanpix)

ly well-to-do. They probably made their own iron from ore extracted from nearby bogs. Several graveyards have been found to the north, west and south of the farm. The most sensational find is a woman's grave that contained a 14-year-old girl who died in about 300 AD. She was buried with a lead spinning wheel and a spindle bearing the remains of textiles, which was very surprising indeed. In addition, the archaeologists found an amber bead, a gold-foiled glass bead, a dragon buckle and an earthen vessel.

"The Ås excavation, site of a large farm with graves from the Iron Age, represents yet another important contribution to our knowledge about this era", Grimsrud points out.

FAMILY AND COMMUNITY

The first centuries after the birth of Christ marked a burgeoning age of innovation in the Nordic countries. The iron axe, the iron sickle and the horse opened new vistas. Most of Denmark was put under the plough, and Sweden and southern Norway offered huge new tracts of arable land. Pioneering farmers cleared forests and picked rock. A number of finds from this period tell of extensive imports of products crafted by Roman artisans. Archaeologists have found bronze pans and glass goblets, but people clearly also longed for more 'up-market' items such as silver goblets, Roman swords and gold jewellery. Locally-made jewellery with mythological motifs appears to have been inspired by Roman art, at the same time as it bears witness to a rich, very characteristic Nordic ornamentation. The pieces also show that the Iron Age was a time of changing styles and fashions, just as we see in our own time. The people must have been in close contact with their neighbours to the south. Many Norseman probably visited the Roman Empire, carrying trade goods such as furs, hides and walrus tusks. Some may also have served as mercenaries. As early as 2000 years ago, sea routes and sturdy seaworthy vessels linked Norway to the rest of Europe.

Archaeologists in Norway and other places used to be dedicated to finding artefacts and burial grounds. Today, archaeology is to a greater extent a field in which researchers strive to learn more about how people lived in times past. At Ås and on other sites, it is the houses, the traces of cooking and other routine activities that really generate interest. Meanwhile, archaeologists are increasingly seeking help from experts in other disciplines, including biology, religion and linguistics.

"As a result, we now know a great deal more about the family and society of 2000 years ago today than we did just a few years ago. This has helped make our field even more exciting", concludes Ole Grimsrud.

A glacial landscape

Ås is a small town about 30 km south of Oslo. From there and further south down the west coast of Sweden, archaeological treasures are far from uncommon. Among the most famous are the many Bronze Age rock carvings that have been found. One of them, at Tanum just across the Swedish border, is on UNESCO's world heritage list. The area is also well known for its Viking Age finds, including the Tune Ship, found in a burial mound and now on display at the Viking Ship Museum in Oslo.

The gargantuan glaciers of the Ice Age largely determined Norway's current topography. The name Ås means 'ridge' in English, and it is no wonder someone gave that name to an ancient farm located here some 2000 years ago. The glaciers created far more than the deep fjords and steep-sided mountains for which Norway is famous. The tremendous force of the glaciers also moved huge amounts of sand, soil and rock, forming the 1000 km-long moraine ridges that dissect southern Scandinavia today. The unfathomable weight of the ice masses also forced the ground down, meaning that most of the land in Scandinavia with an elevation of less than 150 to 200 metres today was once seabed. Soil that has been submerged is rife with nutrients, and the glaciers created a fertile belt along the coastal lowlands south of Oslo. The very best soil is often on the south side of moraine ridges, a fact which did not delude the Iron Age Norsemen.

The glaciers disappeared about 10,000 years ago. Not long after, the first people arrived to live in this place where the coastal waters offered an abundance of fish and seals, and huge flocks of reindeer grazed right down to the seaside. The oldest human artefacts in Norway were found near the North Cape, about as far north as it is possible to get in Europe. But why? For a long time, researchers believed the first Norwegians must have come from the east. However, new examinations of the archaeological traces they left behind tend to point in the direction of Stone Age finds around the North Sea. This probably means that Norway, as we know it today, was populated from south to north, all the way to the Arctic Ocean, just a few short centuries after the end of the Ice Age.

Ski for enlightenment

World champion cross-country skiers have contributed to the development of new knowledge about sliding friction. Now scientists are eager to transfer this knowledge to research in other fields.

BY SIW ELLEN JAKOBSEN

A research project that addressed the optimisation of snow and skiing conditions has helped numerous cross-country skiers improve their 'track times'. Tests have shown that certain skiers have boosted their speed by as much as 10 per cent when the structure of their ski soles is optimally adjusted to the prevailing snow conditions.

"Despite the fact that large parts of our planet are covered with ice and snow, little research has been done on sliding friction. The ski manufacturer Madshus, the Norwegian Olympic skiers and NTNU have now developed fundamental knowledge about sliding friction which can be transferred to a number of other sports as well as to areas outside the world of sports", says Sveinung Løset, professor of Arctic Technology at the Norwegian University of Science and Technology (NTNU) in Trondheim.

"For example, the friction that arises between tyres and the road surface is crucial to safety on roads and runways alike", explains Løset.

Moreover, research on products designed to enhance sliding friction paid off during the summer Olympics in Sydney last year, for example, when they were tested on the Norwegian team's boats in the kayak and canoe events, bringing excellent results.

WALKING ON WATER

The Norwegian research has revolved around how to minimise friction between snow and skis.

"A 'watery film' forms between the snow and the skis", says Gunnar Bjertnæs, technical director at the Madshus ski factory. "The friction is lowest when the watery film is suitably thin. When weather conditions are too cold, it is hard to produce this film so you need to have a structure on the skis that promotes its production. The structure is the pattern made on the sole of the ski to reduce the friction between snow and ski. If the temperature is above freezing, the film becomes overly watery, causing suction rather than friction. Then the skis have to be structured with a pattern that drains the water away. Given this knowledge, it is possible to manufacture skis with optimal sliding properties by adapting the depth and type of sole structure to different snow conditions."

▲ *CROSSING THE FINISH LINE: Little research has been done on sliding friction, yet such research can be decisive for far more than getting Thomas Alsgaard across the finish line. It could make life safer for the general public. (Photo: Ole C.H. Thomassen)*

HI-TECH SKIING

"These days, making skis is a high-tech process, thanks to the R&D we have performed in connection with this project. We no longer sell just skis, but also expert knowledge about the skis", says Bjertnæs. Thomas Alsgaard of Norway, Christian Zorzi of Italy, René Sommerfeldt of Germany, Pirjo Manninen of Finland and the other competition skiers who use Madshus skis benefit from this knowledge.

"Your average cross-country skier will also benefit from the way we ensure the quality of our products these days", concludes Bjertnæs.

The world's oldest ski factory

The research performed by the Madshus ski factory (founded in 1906) has put more than just skiers on track. From producing 50 000 pair of skis a year at the factory in the tiny inland village of Biri in the early 1990s, in 2000, Madshus sold 175 000 pair in 23 different countries. This bodes well for the tradition-rich ski factory on the threshold of its first centenary in 2006.

"When competitors using skis made in Biri step up to the rostrum to accept their prizes, the average skier takes note of the brand name and wants to buy the same kind", states Technical Director Gunnar Bjertnæs. The ski factory was bought out by K2 of the US in 1988, and has for the most part produced downhill skis since then. However, the downhill market has declined significantly. The factory had to adjust accordingly, and it was decided to focus on Nordic skis. Today, the plant is the world's best in this area.

An object-oriented view of the world

It is hard to tell what today's computers would have been like, had it not been for Norwegian researchers Kristen Nygaard and Ole Johan Dahl, who developed the world's first object-oriented computer language in the 1960s. In this day and age, all computer users live in an object-oriented world. But what does the term 'object oriented' actually mean?

BY BJARNE RØSJØ

"Prior to the development of object-oriented computer programming languages, in principle, all computer programs consisted of a long line of commands. Computers were instruct-ed to add one number to another by one instruction, then multiply two other numbers by the next, etc. The programs operated on a sort of single, long assembly line principle, with small incremental variations leading from one particular point of departure to a particular conclusion. By comparison, object-oriented computer languages have many more dimensions and possibilities. We like to think of them as organising the program execution not so much as a single assembly line, but more like in a workshop, with an assortment of components standing ready to accept different types of assignments which are prescribed by a specific program", explains Kristen Nygaard.

Nygaard and Dahl presented the world's first object-oriented programming language Simula in 1965, followed by the sequel, Simula 67, two years later. Yet the real story began long before that, when Nygaard was stationed as a conscript at the Norwegian Defence Research Establishment (FFI) at Kjeller outside Oslo in 1948. His first assignment was to calculate the correct diameter of the uranium rods to be used in Norway's first (and Europe's first civilian) nuclear reactor. As the Americans were not especially forthcoming with the answer, FFI's chief bean counter Jan V. Garwick had to find a mathematical solution for how to calculate the answer.

It was of the utmost importance to calculate a correct diameter for the uranium rods: If the answer was inaccurate, there were two possibilities. Either there would be the disappointment of no chain reaction being initiated among the neutrons in the uranium, or there would be excessive radioactivity which, at the very least, would make the Kjeller area a very uncomfortable place to be.

THE NEUTRON GAME

Nygaard was put in charge of the calculations which were being carried out at that time by hand and using electromechanical calculators. Despite the fact that he enlisted the help of many others, the very complexity of the process resulted in extremely slow progress. Then he and Garwick got a bright idea from a new report from the USA: It should be possible to imitate or simulate the neutron paths in the reactor by constructing a game with the same structure (following the same rules) as the physical phenomenon. They already knew the rules, that is, the probability distribution of how far a neutron will move before it collides with another nucleus, and they also knew the probability of the collision causing a fission, releasing other neutrons.

"It was possible to observe the result of playing the entire 'neutron game' for a few thousand neutrons. In actual practice, the work was done by six or seven soldiers who spent two months doing the necessary arithmetic by hand. And the reactor worked just as it should when it came online in 1951", recounts Nygaard.

The neutron game was Kristen Nygaard's first experience with simulation. From the mid-1950s, his work focused mainly on strategic and tactical studies related to military technology, frequently using simulation as a tool. By that time, early electronic computers were available, but the writing of simulation programs turned out to be very difficult because of the complex interaction patterns inherent in such simulations. In 1960, he moved to, and soon became director of research at, the Norwegian Computing Centre, where he was once again called upon to perform assignments which required simulation to analyse tasks to facilitate planning for private businesses and the public administration.

Nygaard's experience was that the use of simulation entailed two main tasks, both difficult: 1) the system at hand had to be properly understood and described, and 2) the system description had to be able to produce an error-free computer simulation program.

At that point, Nygaard decided to devise a language that was suitable for people who needed to produce precise descriptions of even the most complex systems; descriptions that were comprehensible and useful in human communication, but which also made it possible for a compiler program to automatically produce computer simulation programs of the described systems: the computer could use a description to simulate the system described. The language was to be named SIMULA – an abbreviation for "simulation language".

In 1962, Nygaard recruited his friend and FFI colleague Ole-Johan Dahl to join the team, and the rest is history.

"At that time, I hadn't followed the development of programming languages for a number of years. But Dahl had the expertise I lacked. The first version of Simula was completed in 1965, and it is impossible to tell where Ole-Johan's efforts ended and mine began. Simula is genuinely a joint effort", comments Nygaard 36 years later.

Object-oriented programming languages dominate the field today. Simula was quickly used in very large simulation tasks, for example, in the design of microchips, but also as a general programming language for mastering highly complex programming tasks. From 1976 to 1980, the Simula ideas were introduced into programming tools for work stations from MIT, Stanford and Xerox Parc. 1984 marked the introduction of the Apple Macintosh, the first personal computer based on object-oriented design principles, and eventually Microsoft followed Apple by presenting its own object-oriented operating system, Windows. In the 1990s, Sun Microsystems developed the language Java, which features all the basic object-oriented elements from SIMULA plus important new features related to the Internet.

SHAPING OUR LIVES

Both Kristen Nygaard and Ole-Johan Dahl are highly respected in international professional circles. In Norway, it is Nygaard who is best known – for his political commitment. Among other things, he was leader of the "No to the EU" organisation during Norway's most recent debate on EU membership, and he certainly did his part to ensure that the majority of Norway's voters rejected Norwegian membership of the EU in two national referenda.

In 1968, Ole-Johan Dahl was appointed to the first chair in informatics at the University of Oslo, building up the new Department of Informatics. Nygaard later left the Norwegian Computing Center and joined the same department.

In the autumn of 2000, both men were awarded the Commander degree of the coveted Order of St. Olav for their contributions to the development of computer technology. In December, they were received at the Royal Palace in Oslo, having been granted an audience to thank King Harald for the award in person, in accordance with Norwegian tradition. "As we cut, paste, copy and save our computer files today, we owe a huge debt of gratitude to Dahl and Nygaard", it states in the grounds for why the two professors were awarded the Order of St. Olav.

RECOGNISED FOR THEIR CONTRIBUTIONS: Kristen Nygaard and Ole-Johan Dahl were recently awarded the prestigious John von Neumann Medal for 2002. The prize is awarded by the Institute of Electrical and Electronics Engineers (IEEE), and considered one of the highest distinctions computer scientists can achieve. Last year Nygaard and Dahl were named Commanders of the Order of St.Olav, and had an audience at the Royal Palace to thank King Harald for the award. (Photo: Department of Informatics)

An Arctic environmental laboratory

Some of the highest levels of environmental contaminants ever recorded in untouched wilderness areas were recorded in Lake Ellasjøen on the Arctic island of Bjørnøya, the southernmost island in the Svalbard archipelago.

BY SIW ELLEN JAKOBSEN

Extensive research is currently underway on the island to determine where the environmental contaminants come from, why they end up on Bjørnøya and whether the island is representative of other parts of the Arctic. "Bjørnøya is a unique laboratory for studying the long-range transport of environmental contaminants, particularly since we can rule out that local sources have caused the pollution", comments Trond Skotvold, a researcher at Akvaplan-niva in Tromsø. Along with the Norwegian Polar Institute, the Weather Forecasting Service in Northern Norway, the Research Department of the Norwegian Meteorological Institute and the Norwegian Institute for Air Research (NILU), Akvaplan-niva is involved in identifying the sources and transport mechanisms behind the pollution on the island. "It is important to produce knowledge that the authorities can use in international negotiations to reduce the use and emissions of organochlorine compounds", Skotvold points out.

▶ *SEABIRDS: One theory is that seabirds, and there are huge numbers of them around Lake Ellasjøen, may increase the levels of environmental contaminants through their excrement. (Photo: G. Christensen/Akvaplan-niva)*

SOMETHING FISHY ABOUT ARCTIC CHAR

Skotvold was among the first to become aware of the unusually high accumulation of environmental contaminants on Bjørnøya. Strangely, the facts were revealed as the result of an accident. In the summer of 1992, fish samples were collected in Lake Ellasjøen on Bjørnøya, then preparations were made to analyse them for mercury and organic environmental contaminants. In addition to the official samples, Skotvold fished an Arctic char intended for his own family's dinner table. He took the fish home with him and put it in his deep freezer in Tromsø to await a suitable occasion. However, there was a mix-up at the laboratory, and the samples were analysed for mercury only. Suddenly, the lone fish in the freezer was the only remaining untested material from the original sample. With a heavy heart, the scientist sent his magnificent Arctic char off to the Norwegian Institute for Air Research (NILU) to have it checked for organic environmental contaminants. The readings were right off the scales; the char contained extremely high levels of DDT and PCBs.

As a result of the discovery, Akvaplan-niva performed a number of surveys on lakes on Svalbard and Bjørnøya from 1992 to 1998. The surveys of freshwater sediments and fish indicate that Lake Ellasjøen is totally unique. It has the highest PCB and DDT readings ever recorded in untouched Arctic freshwater environments. Other lakes on Bjørnøya or in northern Norway have nowhere near the same high levels.

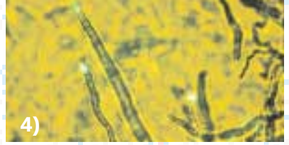
HAZARDOUS BREEZES

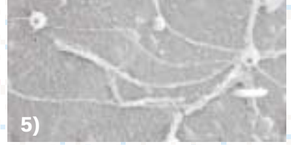
Researchers are now trying to figure out why Lake Ellasjøen differs so much from the other lakes. They believe that various meteorological conditions, combined with the prevailing topographical conditions, may be the answer. "Lake Ellasjøen is located right beside a mountain, meaning more precipitation is deposited there. Thus the deposit of airborne components may also be greater than in lakes situated in flat terrain", explains Skotvold.

Another theory is that seabirds, and there are huge numbers of them around Lake Ellasjøen, may increase the levels of environmental contaminants through their excrement. There are strong indications that the environmental contaminants found in this area are transported from the distant south. Special climatic conditions cause the contaminants to be transported by air and deposited in a delimited area of the Arctic. Accordingly, researchers are collecting samples of rain, snow and fog, then collocating them with wind currents to determine their origins.

DDT and PCBs are substances with very long half lives. These days, they are banned in the West, but still used in some developing countries, and probably also in Russia. DDT is used to fight malaria and as a pesticide in agriculture. PCBs have been used *inter alia* in transformer and hydraulics oils, as well as in electric heat exchangers. Researchers currently know very little about the effects of the toxic concentrations on Bjørnøya, so further research needs to be done on the question.

TOXIC BEAUTY: The pristine Lake Ellasjøen on Bjørnøya (Bear Island) contains extremely high levels of environmental contaminants. The extensive research being done on the island is aimed at finding out why the contaminants end up here. (Photo: G. Christensen/Akvaplan-niva)





▶ *MOONSCAPE: When pieces of lava from the mountain ranges off Costa Rica are placed under the microscope, we see structures and shapes the size of micro-organisms. The pictures (1–6) show volcanic glass, including the biodegradation and conversion of the glass along the internal fractures (1 and 2). All the pictures expose canals, structures and formations containing DNA. The visible DNA is in the dissolved canals inside the glass (1 and 2).*

Rocky Road

▲ *LAVA PILLOWS: This is a sample of volcanic rock recovered from a depth of >2000 metres on Mohn's Ridge. The sample is from pillow lava, and it is in the outermost layer where traces of life have been found.*

▲ *ROCK AND ROLL: Researchers attempt to collect samples from the seabed in the North Atlantic using the ROV Aglantha.*

Deep water or deep space? Scientists hope that volcanic rock-eating subsea bacteria can help us solve some of the mysteries of outer space.

BY PAUL TORVIK NILSEN

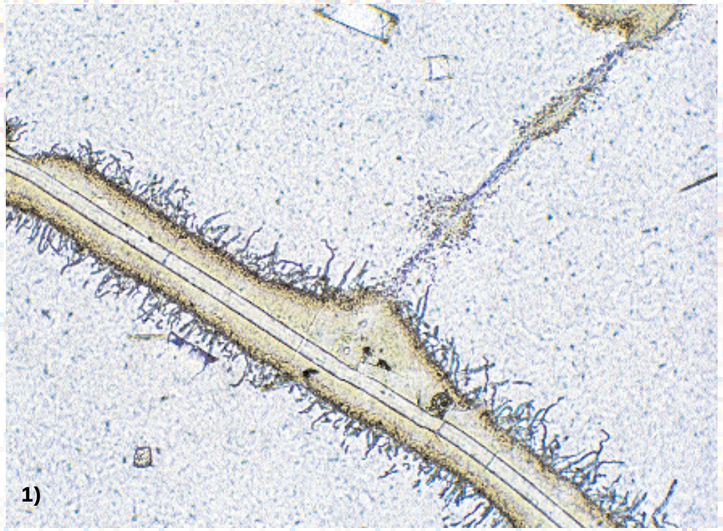
PHOTOS: THE DEPARTMENT OF GEOLOGY, UNIVERSITY OF BERGEN

Geologists and microbiologists at the University of Bergen have shown that there are micro-organisms living in cracks in volcanic rock several hundred metres beneath the earth's crust under the seabed. They found their evidence in samples from volcanically active areas (spreading ridges) in the North Atlantic between Norway, Svalbard and Greenland, and in the Pacific off the coast of Costa Rica.

THE MYSTERIES OF SPACE

"Today, many researchers believe that life began under the ocean floor, deep in the earth's crust. Accordingly, micro-organisms from volcanic rock at great depths may possibly tell us something about the origin of life. The mere fact that there is life far below the Earth's surface is also a crucial point when we set our sights on learning more about planets other than our own", remarks Researcher Ingunn Thorseth, Department of Geology, University of Bergen, where she is a specialist in the field of geomicrobiology. Along with geology professor Harald Furnes and researcher Terje Torsvik at the Department of Microbiology, Thorseth is a pioneer in this field of research.

The first signs of microbial life in volcanic rock were discovered in 1991. In 1995, researchers managed to prove that lava found several hundred metres under the ocean floor contained microbes.



Many of the methods used by the geologists and microbiologists are the same as space researchers use when searching for possible life on Mars and other planets. Scientists are now better able to recognise signs of life – or something that might once have been life – also on other planets. They are also always trying to find new ways to search for such life.

"First of all, space researchers can look for traces of life, alive or petrified (fossils), in species of rock on planets and moons where we believe there may have been or is water. This applies to Mars, in particular, but also to Europa, one of the planet Jupiter's moons. Both may have or have had water or ice on the surface", Ingunn Thorseth points out.

DNA FINDS

When volcanoes erupt, they spew out red-hot, liquid magma and lava, i.e. melted stone from the earth's core. Researchers use scraping tools, as well as manned and unmanned submarines, to pick up volcanic rock from the uppermost layer, on the surface of the ocean floor. Thanks to the Ocean Drilling Programme (ODP), they also have equipment to take drill cores at depths of several hundred metres, from the older, underlying strata of such volcanic rock.

Two such cores (504B and 896A) have been drilled off the coast of Costa Rica; the one all the way down to roughly 2000 metres. The rock there is six million years old, and it was in samples from these drill cores that researchers first found traces of micro-organisms under the seabed.

When molten basalt gushes out into the icy cold seawater, it hardens quickly, forming pillow-like structures or pillow lava, as it is often called. The cooling is so abrupt that the lava in the outermost layers does not have time to crystallise, but hardens instantly into a dark glassy material. This glassy fringe is usually heavily fractured. In contact with seawater, the glass along the cracks gradually deteriorates and breaks down. Researchers study the biodegradation process under electron microscopes. In so doing, they have discovered that the glass is full of minuscule dissolved canals and so-called spherical vacuoles, the size and shape of micro-organisms.

"The discovery is difficult to explain based on purely organic biodegradation processes. Using special coloration techniques, we have managed to show that such dissolved canals and vacuoles contain DNA. The DNA finds prove that micro-organisms live in the lava, and they have left behind traces in the glass through small 'biosignature' pits and thin canals", reports Thorseth.

In 1999, researchers in Bergen began investigating lava flows from volcanic spreading ridges that extend across the ocean depths stretching from Iceland, between Svalbard and Greenland, to the Arctic Sea. These studies are part of the SUBMAR Programme funded by the Research Council of Norway, an interdisciplinary survey of the Arctic spreading ridges.

◀ *ROCKY ROAD: Researcher Ingunn Thorseth of the Department of Geology, University of Bergen, places lava samples under an electron microscope that magnifies them thousands of times. Images of the rocks appear on-screen, allowing her to study what is inside them.*
(Photo: Paul Torvik Nilsen)

Researcher Terje Torsvik of the Department of Microbiology confirms how sensational these finds really are: "This means that rock is not biodegraded solely by ice and water, but also by microbial processes. It was previously assumed that life has been limited to a thin layer outermost on the earth's crust. These finds demonstrate that the biosphere continues for several hundred metres under the seabed, ", explains Torsvik.

GLASS-EATERS

The volcanic rock has dissolved in the areas where micro-organisms have taken up residence. Researchers contend that bacteria actually eat the rock, taking nourishment from the surface of the glass.

"By investigating young lava flows from the Arctic volcanic ridges in the Atlantic, researchers can perform tests to determine which types of microbes live in the pillow lava. We have observed several different cell shapes: spherical (coccus), rods and cells with long, thin branching stems. The cells become gradually covered by metal precipitates. Even long after the cells are dead, it is possible to recognise them from the metal cap that takes the shape of a fossilised cell", continues Thorseth.

"The bacteria live without sunlight (photosynthesis), and have little access to organic material. By extracting DNA from the basalts and culturing the microbes in the laboratory, we can identify the microbes and find out what they live on", remarks Torsvik. "One possibility is that the bacteria get their energy from hydrogen or methane, which may be pre-sent in dissolved gas in the pore water. Another possibility is that they get energy from oxidising reduced iron, manganese or sulphur compounds in the rock. Some of the bacteria are anaerobic, while others are aerobic. All exist without sunlight. Many of them may build their cells out of carbon from carbon dioxide dissolved in the water, just as plants do", explains Torsvik.

A WHOLE NEW WORLD

Finding organisms in the rock under the seabed is considered a major scientific discovery. Researchers have barely 'scratched the surface' in their investigations of this life, but the new century looks highly promising when it comes to learning more.

Facts about ODP

The Ocean Drilling Programme (ODP) is a co-operative international project being conducted by research institutions that target the exploration of the Earth's structure and the development of deep-sea drilling. The programme is funded by 20 nations. ODP gives researchers access to the drilling vessel *JOIDES Resolution*, which makes six cruises each year. The vessel can handle depths in excess of 9000 metres using a drilling string that makes it possible to take core samples from most of the Earth's seabed. The *Joides Resolution* is equipped with modern laboratories, including a new microbiology laboratory recently set up onboard as a result of the discovery of a deep bio-sphere under the seabed. As from 2003, plans will be made for a new phase of the programme called the Integrated Ocean Drilling Programme (IODP), and a new drilling vessel is currently under construction in Japan. The exploration of the Earth's deep biosphere will be a central theme for ODP and IODP in the years ahead.

Them bones, them bones, them ...brittle bones

Osteoporosis is a growing problem throughout the western world, but Norway tops the charts. Why? Scientists are still searching for the answer, and some of the most exciting efforts to solve the mystery are being made in Norway. Perhaps the answer lies in Norwegians' genetic make-up.

BY BÅRD AMUNDSEN

BRITTLE BONES: Norwegians are the most brittle-boned people in the world. One of three Norwegian women and one of 10 Norwegian men develop osteoporosis. Norwegian researchers believe the cause is genetic.
(Photo: Lucky Look/megapix.no)

WEAK BONES: Several comparative studies indicate that Norwegians have weaker bones than people who live elsewhere.
(Photo: NPS/P. Motta)

One of three Norwegian women and one of 10 Norwegian men develop osteoporosis at some point in their lives, making the disease one of Norway's most serious medical problems. Of a population of approximately 4.7 million people, some 250,000 women over the age of 50 are brittle boned. Sooner or later, most will break an arm or a leg – or two. The most serious fractures are those of the hip, as evidenced by the fact that about 1100 Norwegian women die following hip fractures each year.

The number of Norwegians suffering from osteoporosis is increasing explosively, leading in turn to a 500 per cent increase in the number of hip fractures over the past 40 years. Experts talk of a Norwegian "epidemic" of osteoporosis and fractures, fearing the incidence may re-double over the coming decade or two.

MASS DESTRUCTION?

Osteoporosis is diagnosed on the basis of bone mass density. People with less than a certain amount are defined as having osteoporosis. Fractures can occur even as a result of light strains, and serious fractures can result in chronic pain, or even in death, as mentioned above.

Bone mass, i.e. the skeleton, is built up during childhood and adolescence. At some point in a person's 20s or 30s, the body completes the job, at which time the process of 'mass destruction' begins slowly but surely, continuing for the remainder of an individual's life. Osteoporosis is more prevalent among women as they reach menopause around the age of 50 and their bodies gradually stop producing such large quantities of oestrogen, the hormone which plays a major role in bone mass retention.

The pace of the brittle-bone boom has increased even more rapidly among men than women in recent years, and researchers predict that osteoporosis will affect one in 10 Norwegian men. Their "Achilles heel" seems to be their vertebrae.

A BONY ENIGMA: Sjur Reppe and his research colleagues at the University of Oslo are searching for the genes that hold the answer to the mystery of osteoporosis. (Photo: Rolf Chr. Ulrichsen)

GENES?

What can be causing this osteoporosis epidemic? Quite frankly, no one knows, but extensive research is being conducted to solve the mystery, and some of the most exciting projects are taking place in Norway.

A group of scientists at the University of Oslo is taking a closer look at Norwegians' genes. Researchers suspect that as many as two of three Norwegians with osteoporosis can blame the disease on their genes, and they have now set out to identify which gene is causing the problem.

Bone mass formation is a highly complex process. Thus far, scientists have determined that it is regulated by a hormone called parathyroid hormone (PTH). Learning that, in itself, was an important step forward.

"First, we tried to isolate all the genes that govern skeletal formation in humans. We started with PTH, isolating all the genes the hormone regulates in bone cells or their precursors, osteoblasts. We have already made considerable progress with this, having identified more than 100 bone cell genes regulated by this hormone", comments Dr. Sjur Reppe at the Department of Medical Biochemistry at the University of Oslo. The next step is to see whether these genes are expressed differently in patients with osteoporosis than in healthy individuals. The project has been welcomed with enthusiasm, receiving grants from the Norwegian State as well as from private associations dedicated to fighting osteoporosis. It has also won several international research prizes.

"Once we locate the appropriate genes, we believe we can develop a laboratory test to indicate individuals' predisposition for osteoporosis before they begin breaking bones", says Reppe. The research being conducted at the University of Oslo also opens up new possibilities for developing medicines to prevent and treat osteoporosis.

Why Norwegians?

Researchers associate the widespread osteoporosis seen in Norway with several factors, but they have not agreed on the explanation for the phenomenon. Among the potential explanations: Norwegian are tall, eat little fatty food and get limited sunlight, putting them at risk for vitamin D deficiency.

Several comparative studies indicate that Norwegians have weaker bones than people who live elsewhere. One such study was a major international survey which concluded that women and men in Norway's capital city of Oslo had the lowest average bone density among the populations of 16 major European cities. Several theories have been put forward to explain why.

• Calcium and vitamin D are two key factors in bone mass formation. The body needs vitamin D to make use of calcium. Few other populations ingest more dietary calcium than Norwegians, not least because they drink more milk per capita than anyone else. However, all that calcium does not seem to be strengthening bone mass. Maybe that means the missing factor is vitamin D? Sunlight is an important source of vitamin D, and there is not much sunlight in Norway during the long months of winter. Yet Norway is a long, narrow country, stretching from north to south, and people in Oslo, located in the southern part of the country, break their hips twice as often as those who live in Arctic Finnmark County, where the sun fails to breach the horizon for months on end.

• Norwegians eat less fatty food than most other peoples in the western world. While that is good for the heart, it is not necessarily good for arms and legs. In Norway, thin women are far more 'breakable' than their more statuesque sisters. There are two explanations for this. First, fat, not least fat on the hips, will cushion a fall. Second, fat has a certain ability to produce oestrogen, meaning that having a few extra kilos helps compensate for the post-menopausal decline in women's oestrogen production.

• Norway is a cold country. It is slippery large parts of the year. There is a genuine risk of falling on icy streets and pavements. For quite some time, it was believed that this was probably the main explanation for the myriad of bone fractures among senior citizens in Norway. However, a closer examination of the statistics showed that almost as many fractures occur among the brittle-boned in summer as in winter. Another salient fact is that 70 per cent of the fractures occur indoors.

• Norwegians are tall. This has an adverse impact on fracture statistics. For example, for women, 10 centimetres of height translates into a 50 per cent increase in risk of hip fracture. This may be because tall people have the highest centre of gravity and thus a longer way to fall.

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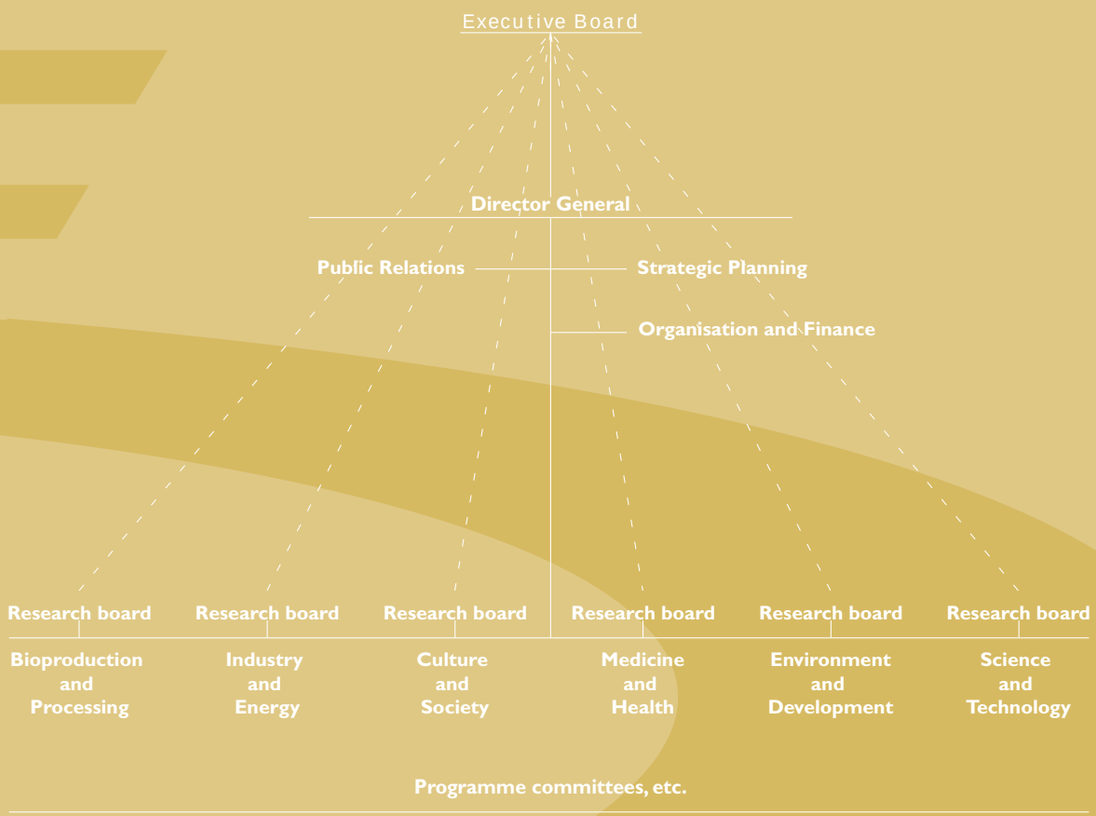

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A lousy thief

A LOUSY DEAL?: A large number of the drugs available at the pharmacy today are based on ingredients from plants' defence systems. (Photo: Harald Husebye)

A tiny louse specialises in stealing plants' immune defences and then turning them to its own advantage.

BY SIW ELLEN JAKOBSEN

A louse, bearing the Latin name *Brevicoryne brassicae*, is able to drill into selected cells in a plant's vascular tissue without triggering the plant's immune defence system. Then it steals the plant's immune defence system, and incorporates it into its own defence system.

A BUG IN THE SYSTEM

A research group at the Norwegian University of Science and Technology (NTNU), in Trondheim, has discovered this sophisticated behaviour, thus revealing one of the most audacious, cunning thefts scientists have ever seen.

The project is an example of how genetically manipulated plants open new opportunities for studying biological processes of considerable economic and scientific interest.

Atle Bones, professor of molecular biology, and his group of scientists at the Department of Botany at NTNU have been studying the transmission of signals from cell to cell and the reorganisation of plants' defence systems. The largest 'home-made' collection of genetically manipulated plants in Norway is available for use in these studies. Genetically manipulated plants (GMP) are an increasingly important tool for research projects, and the group began to make GMPs and to study the effects of the genetic modifications early on.

BAMBOOZLING THE PLANTS

The louse *Brevicoryne brassicae* destroys the harvests of a number of cruciferous plants, including rapeseed, worth a fortune every year. The louse infests a group of plants that contain sulphurous compounds that researchers have long been interested in investigating. Known as glucosinolates and cyanogenic glucosides, the compounds are found *inter alia* in rape, oats, broccoli, legumes and mustard. These substances have proven essential for the plants' defences against insects and fungus, and they have also been known to stop *Brevicoryne brassicae*. But the louse generally manages to dupe the plants. Using an incredibly sophisticated stinger, it searches out the defence substances and steals them from special cells in the plant. This is nature's own example of precision deepwater drilling!

The louse subsequently takes the plant's defence substance and uses it in its own defence system. When attacked by a predator insect, the louse activates the 'stolen' glucosinolate compounds as well as its own enzymes, making it exceptionally poisonous.

MAKING GENOME CHIPS

Using genetic engineering/manipulation, researchers have managed to extract the relevant genes from the plants and insects, at the same time as they have been studying the sophisticated theft of defence substances while the plant and insect are alive. This particular natural phenomenon is considered so interesting that a number of other groups of scientists at NTNU and Planteforsk at Ås, i.e. botanists, plant physiologists, entomologists and bioinformatics experts, are joining forces for a major research push to examine it in more detail. Bones reports that they are in the process of making a genome chip. This is a technology in which all the plant's genes (the simplest plant has 25,500 genes!) are 'spotted' onto a glass chip. At that point we can measure how active each individual gene is when the louse is on the plant, and when it is not. The advantage is that this allows us to compare the response of all the genes in the plant at the same time under different conditions.

Glucosinolates also have a medicinal effect: Animal testing has shown fission products such as iso-thiocyanates to be potentially anti-carcinogenic. This is part of the reason why broccoli is good for us, for example.