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Bioprospecting in the Arctic

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Foreword

For many years bioprospecting has been one of the most controversial issues in environmental diplomacy. A key development in this debate was the negotiation of the 1992 Convention on Biological Diversity. While much of the debate on bioprospecting has centered on the mega-diverse tropical countries of the developing South there has been only limited focus on whether bioprospecting is also an issue for other regions of the world. However, recent developments in biotechnology developed from the biodiversity of other areas of the planet such as Antarctica and the deep-sea beyond national jurisdiction (highlighted in previous reports by UNU-IAS) clearly show that both scientific and commercial interest in biodiversity is no longer just confined to the mega-diverse countries of the South.

This growing scientific and commercial interest in the biotechnology potential of extreme and isolated environments has in turn presented new challenges for environmental governance, especially in areas beyond national jurisdiction. Debate on the need for or desirability of regulation of bioprospecting in such environments is the focus of current debate in several international forums including those associated with the Antarctic Treaty System, the Convention on Biological Diversity and the United Nations Convention on the Law of the Sea.

One of constant themes emerging in the debate in all of these forums, but especially in the Antarctic context, is the lack of detailed information on the nature and scale of bioprospecting in these environments. Surprisingly in the context of the debate in Antarctica so far there has been little if any consideration of the Arctic experience, and the lessons that experience may offer for a response to this issue in the Antarctic. While there are obviously significant differences between the two regions (not the least being the fact that much of the Arctic is the sovereign territory of individual Arctic States) data on the extent and nature of bioprospecting in the Arctic may be useful in helping policy makers consider future scenarios and trends in bioprospecting in the Antarctic.

This report represents a timely contribution by UNU-IAS to an emerging debate towards the end of the International Polar Year (IPY). The IPY is a large international collaborative scientific research program focused on the Arctic and Antarctica involving over 200 scientific research projects, with thousands of scientists from over 60 nations examining a wide range of physical, biological and social topics.

While research conducted by UNU-IAS has been conducted independently of the official IPY research program it nonetheless complements the main IPY research agenda. UNU-IAS's work on the polar regions during this period has included a range of activities including the research presented in this report, contribution of an update on bioprospecting in Antarctic to the 30th Antarctic Treaty Meeting in New Delhi, India, the development of a web based bioprospecting database tool and convening of an international symposium for experts in polar law and policy to consider bioprospecting and other emerging issues for the polar regions beyond the IPY.

It is against this background that data presented in this report seeks to highlight the nature and extent of bioprospecting in the Arctic. We hope this data will be useful for policy makers in the Antarctic context. It also highlights that bioprospecting is an emerging issue for the Arctic and we hope it will prove useful for Arctic policy makers as well as for policy makers beyond the Polar Regions.

A.H. Zakri
Director, UNU-IAS
March 2008

Executive Summary

This report examines the extent and nature of bioprospecting in the Arctic. It argues that there is significant interest in the biotechnology potential of Arctic biodiversity. In many cases this potential has moved beyond the research of the academic community to commercialisation by industry. In fact, given the number of companies involved in research on or the actual exploitation of biotechnology based on Arctic genetic resources (fourty three companies in total) one clear conclusion is that this industry, in various forms, is well established. This conclusion is supported by the existence of more than thirty one patents or patent applications based on Arctic genetic resources.

Biotechnology based on Arctic genetic resources covers several key areas including enzymes (including those used in life science research and a range of industrial applications), anti-freeze proteins, bioremediation, pharmaceuticals, nutraceuticals and dietary supplements, cosmetics and other health care applications. There is also a significant focus of marine biotechnology research and development (R&D).

One of the outstanding questions in the debate on bioprospecting in Antarctica is whether commercial interest in Antarctic genetic resources is more than just a momentary diversion from the "pure science" [sic] upon which the framework of Antarctic governance is built? The findings presented in this report lend considerable support to the argument that it is not. The overwhelming conclusion of this report is that R &D in relation to the biotechnology potential of Arctic genetic resources and the actual commercialisation of such research is occurring on a significant and ongoing basis. Arguably this might suggest that one could expect to see similar developments in relation to biotechnology based on the genetic resources of the Antarctic. Although this is by no means certain. Whether bioprospecting and development of biotechnology from Antarctica will ever match that of the Arctic remains to be seen. Nonetheless the existence of established R&D programs and considerable commercial activity based on Arctic genetic resources should not go unnoticed as the international community further considers the implications of the emergence of bioprospecting as a new commercial activity in Antarctica and beyond.

1. Introduction

1.1 Environmental Challenges for the Polar Regions

Both the Arctic and Antarctica have become accessible to commerce and industry. In the Arctic technological advances and changes in the Arctic environment due to climate change have made access to the Arctic's oil and gas resources a reality.[1] Similarly as the Arctic ice cap melts new lucrative shipping routes from Asia to Europe are opening up. Perhaps even the North-West Passage will finally become a lucrative ocean highway for international trade.[2] Fishing grounds in the Arctic may also become more accessible and increased sea borne tourism to the Arctic is also a possibility.[3] At the other end of the earth climate change is also having a significant impact on Antarctica. In addition ever increasing human activities in Antarctica are placing new pressures on one of the world's last great pristine wilderness areas. For example in the 2006-2007 Antarctic Austral Summer Season some 28,226 ship borne and land based tourists visited Antarctica.[4] Likewise fishing in the Southern Ocean and waters surrounding Antarctica is a very lucrative business. So lucrative in fact that there is increasing evidence of the involvement of organised crime, especially in fishing for high value fish stocks such as the Patagonian toothfish.[5]

As never before the Arctic and Antarctica are increasingly of interest to commerce and industry. For Arctic communities these new commercial opportunities may bring economic benefits, but they also bring with them new challenges for the sustainable management of Arctic ecosystems and resources and possibly unforeseeable social impacts. The impacts of established and emerging commercial activities in Antarctica also present challenges for the sustainable management of Antarctic ecosystems and resources. A problem made even more complex by the fact that the Polar Regions, especially the Arctic are undergoing rapid environmental change due to the impacts of climate change. With climate change many of the species of the frozen environments of the Arctic and Antarctica, including the microorganisms of the sea ice of interest for biotechnology, appear threatened with extinction this century.[6]

This report focuses on one more emerging commercial activity shared by both Polar Regions, namely bioprospecting. Debate on the many issues surrounding bioprospecting in the Polar Regions has so far been exclusively confined to Antarctica.[7] There has been little detailed consideration of whether bioprospecting is occurring in the Arctic, and the regulatory implications of such activities for the sustainable use of Arctic biodiversity and environmental governance in the Arctic more generally.[8]

While there are many significant differences between the Arctic and Antarctica, examination of the Arctic experience of bioprospecting is directly relevant to the emerging debate in Antarctica.[9] Arctic States have regularly suggested that the Antarctic Treaty System could benefit from consideration of the experience of Arctic States and peoples in dealing with issues relating to environmental governance. In that regard new data on the extent and nature of bioprospecting in the Arctic may be useful in helping policy makers consider future scenarios and trends in bioprospecting in the Antarctic. Understanding the nature and extent of commercial interest in the genetic resources of the Arctic should help us to understand whether commercial interest in Antarctic genetic resources is more than just a momentary diversion from the "pure science" [sic] upon which the framework of Antarctic governance is built.[10] The way in which Arctic legal and policy systems have dealt with the bioprospecting question within their respective jurisdictions might also provide some guidance on what issues the Antarctic regime will need to tackle and the possible challenges ahead.[11] Finally and perhaps indirectly, examination of the Arctic experience for Antarctic purposes could also highlight areas of reform needed in Arctic jurisdictions.[12]

1.2 Structure of this report

It is against this background that this report presents a survey of biotechnology based on the genetic resources of the Arctic including data on the nature and extent of bioprospecting in the Arctic. Examination of the extent and nature of bioprospecting in the Arctic in this report is broken into 6 sections including this introduction. Section 2 of the report provides a definition of biotechnology and bioprospecting in the context of the Arctic. Section 3 goes on to provide an overview of the main areas of scientific research in relation to the biotechnology potential of Arctic genetic resources and give some examples of ongoing projects in the Arctic. This overview is based on a survey of academic and other published literature identified during the course of this research and interviews with researchers conducted by the author.

Section 4 then presents data on companies active in the commercial exploitation of biotechnology based on Arctic genetic resources. Section 5 then presents an analysis of the extent of patenting in relation to inventions based on Arctic genetic resources. The report then concludes in section 6 by briefly considering the implications of the findings presented in this report for the debate on regulation of bioprospecting in Antarctica and beyond.

2. What do we mean by biotechnology and bioprospecting in the Arctic context?

2.1 The Polar environment

The greater proportion of planet earth is cold, rarely rising above 5°C.[13] As one eminent scientist has observed

> "Most biologists tend to neglect the fact that the dominant environment of the biosphere is cold. The Polar Regions and the oceans are 14% and 71% of the earth's surface, respectively. More than 90% (by volume) of the oceans is 5 C or colder."[14]

Low temperature or cold environments prevail and are to be found in fresh and marine waters, polar and high alpine soils and waters, and glaciers.[15] These habitats support a range of organisms from fish and mammals that have adapted to living in these harsh environments, as well as numerous communities of cold-adapted microorganisms known as psychrophiles and psychlotolerant microorganisms.[16] While there is some debate within the scientific community as to the difference between the two it is generally accepted that psychrophiles are defined as organisms that grow optimally at less then 15°C and to a maximal temperature of no greater than 20°C.[17] On the other hand psychrotolerant microorganisms (also known as psychrotrophs) are "defined by their ability to grow at low temperatures, but with optimal and maximal growth temperatures above those of psychrophiles."[18]

Psychrophillic organisms live at the lowest temperatures which allow life to exist and are found not only in the Polar Regions, but also in mountains and the deep sea and therefore comprise a sizable part of the biosphere.[19] Many such organisms are found in the polar seas and associated ice packs. Sea ice, for example provides a vast low-temperature habitat for many organisms, including a broad range of species of bacteria, fungi, algae, protozoa and metazoan which can persist at extremes of known physiological tolerance of temperature and salinity.[20]

Microorganisms comprise greater than 95% of the living material in the ocean. If viruses are also included, then nearly all of the biomass in the ocean is microbial. Consequently, almost all of the genetic diversity and genetic resources in the ocean lie within the microbial components. Despite the overwhelming dominance of marine systems by microbes, their genetic diversity remains relatively unknown. For example, the majority of genes in viruses isolated from the sea have no recognizable similarity to other genes that have been sequenced.[21] Similarly, the vast majority of marine genes have no recognizable similarity to other genetic sequences.[22]

2.2 The biotechnology potential of the Arctic environment

As science starts to understand the diversity of life in these and other extreme environments their potential for use in developing novel biotechnology is slowly becoming understood. A fact taken for granted by all researchers and policy makers in the field of biotechnology, but one which although obvious is often forgotten, is that research into novel biotechnology is at its core intimately connected to biodiversity. As Cowan has noted

> "Biotechnology is a 'natural product' of biodiversity! New products and processes, the keys to the future development of biotechnology, are as dependent on new sources of biomaterials as on the scientific ingenuity required to discover, evaluate and develop such resources. It must follow therefore that the greater the biodiversity; the greater the opportunity for discoveries that may ultimately be translated into valuable biotechnologies."[23]

Thus biotechnology "is based on the search for and discovery of exploitable biology."[24] This search and discovery

> "starts with the assembly of appropriate biological materials, moves through screening for a desired attribute and selecting the best option from among a short list of positive screening hits and culminates with the development of a commercial product or process."[25]

This whole search and discovery process is what is commonly called bioprospecting or biodiscovery.

Most surveys and policy documents dealing with biotechnology would generally define biotechnology in terms of the definition provided in Article 2 of the 1992 Convention on Biological Diversity, that is "any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use."

Similarly the OECD has defined biotechnology as

> "the application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services."[26]

The list based definition of biotechnology developed by the OECD (see Box 1 below) also provides a useful checklist of typical techniques involved in R&D of biotechnology in the Arctic and other contexts.

For a long time the search for and exploitation of natural products and or derived natural products and properties have been the mainstay of developments in biotechnology.[28] Marine natural products especially are now taking a leading role. For example in the most

BOX 1: OECD LIST-BASED DEFINITION OF BIOTECHNOLOGY

DNA/RNA: Genomics, pharmacogenomics, gene probes, genetic engineering, DNA/RNA sequencing/synthesis/amplification, gene expression profiling, and use of antisense technology.

Proteins and other molecules: Sequencing/synthesis/engineering of proteins and peptides (including large molecule hormones); improved delivery methods for large molecule drugs; proteomics, protein isolation and purification, signaling, identification of cell receptors.

Cell and tissue culture and engineering: Cell/tissue culture, tissue engineering (including tissue scaffolds and biomedical engineering), cellular fusion, vaccine/immune stimulants, embryo manipulation.

Process biotechnology techniques: Fermentation using bioreactors, bioprocessing, bioleaching, biopulping, biobleaching, biodesulphurisation, bioremediation, biofiltration and phytoremediation.

Gene and RNA vectors: Gene therapy, viral vectors.

Bioinformatics: Construction of databases on genomes, protein sequences; modelling complex biological processes, including systems biology.

Nanobiotechnology: Applies the tools and process of nano/microfabrication to build devices for studying biosystems and applications in drug delivery, diagnostics etc.

Source: OECD Biotechnology Statistics 2006.[27]

recent published survey of literature in relation to scientific research on marine natural products, Blunt et.al highlight that in 2006 283 scientific articles were published on marine natural products describing some 779 new compounds.[29] Recent reviews of patent data also highlight this trend.[30] Marine flora and fauna continue to provide a vast source of novel lead compounds for the development of pharmaceuticals in particular with more than 52% of those leads coming from sponges.[31]

Perhaps more significantly for the purposes of the present study data published in 2007 also shows that for the period 2001-2005 as compared for the period 1965 to 2005 there was a 27% increase in the number of phyla sampled from the Arctic identified in the published literature.[32] This compares to a 23% increase for the same period sampled for Antarctica.[33]

While natural products are still at the forefront of developments in biotechnology in the past decade biological research and bioprospecting has undergone a paradigm shift.[34] Previously biotechnology R&D was based on the methodology of so called "traditional biology", that is it was premised on a search strategy "based upon specimen collection, system observation, and laboratory experimentation in order to organize knowledge in a systematic way and to formulate concepts."[35] More recently such research is increasingly based on the methodology of bioinformatics. Bioinformatics is a search strategy "based upon data collection and storage and the mining (retrieval and integration) of the databases in order to generate knowledge (the understanding of what is important about a situation) from information or data (the sum of everything we know about a situation)."[36] Applying this approach many developments in biotechnology today also stem from genomics or an approach to the biology of organisms through their genetic blueprints.[37]

The wholesale screening of large collections of micro-organisms sourced from nature is now a widespread R&D strategy in the biotechnology industry. As Ferrer et. al note

> "Nowadays, many research institutes and companies have established collections of microorganisms from a variety of 'common environments' (e.g. soil and seawater) and extreme environments (e.g. hot springs, Antarctic ice, etc). These arrays of microorganisms can be screened and candidates selected for their abilities to synthesize pharmacologically active metabolites and to deliver novel biocatalysts"[38]

Several companies identified later in this report hold vast collections of microbes from the Arctic and other extreme environments which they screen for customers and for their own research purposes.

2.3 Marine biotechnology in the Arctic context

As noted above marine biodiversity is increasingly the focus of much biotechnology R&D. At the outset it is worth noting that this trend is also very evident in biotechnology R&D in relation to Arctic genetic resources. In fact it is clear that there is a very strong focus on marine biotechnology R&D in the Arctic. Therefore some brief clarification of what marine biotechnology involves is warranted before proceeding further.

Research in relation to marine biotechnology can take many forms and is not just confined to the development of novel biotechnology from wild genetic resources. It also includes activities in broad fields of aquaculture, such as improving production of marine organisms through development and production of healthcare products for farmed fish, and the development of new and improved breeds of farmed fish and biotechnology-based reproduction techniques.[39] Marine biotechnology can also involve the production of novel products from marine raw materials including chitin and related compounds from shellfish waste; omega 3 and other fatty acids from fish oils; carotenoids, pigments and flavourings; compounds derived from marine algae such as alginates and carageenans; as well as other nutritional supplements.[40] Nearly all these forms of marine biotechnology are evident in research in relation to Arctic genetic resources discussed in this paper. Some of these activities are highlighted in later sections of this report including in Table 3.

While there is clearly significant commercial interest in marine biotechnology in the Arctic it has not been possible to quantify this in dollar values. However, discussion in later sections does go some way to shedding light on the value of marine biotechnology in the Arctic by highlighting data on the number of companies active in this field, and the nature and extent of patenting associated with such R&D.

Part of the problem in trying to quantify the monetary value of marine biotechnology (and indeed biotechnology in general) in the Arctic stems from the lack of clear global data on the value of marine biotechnology. Although there have been a number of studies of the commercial value of marine biotechnology, it is difficult to accurately place a figure on the commercial value of marine biotechnology as assessment methodologies vary considerably. Some studies have attempted to give a global view of the marine biotechnology industry. For example, one recent study estimated that in 2004 marine biotechnology globally was valued at €2.2 billion excluding aquaculture, seaweed and processing related industries.[41] Other studies have focused on specific market values of industries commonly using marine genetic resources and approximate annual sales of selected marine-based products.[42] For example, one cancer-fighting agent alone sourced from marine sources has annual sales of US$1 billion in 2005.[43] Regardless of what the true commercial value of marine biotechnology actually is, it is certainly a substantial market.[44]

3. Scientific research and development of the biotechnology potential of Arctic genetic resources

3.1 The main areas of research focus

Although there is considerable research in relation to all fields of biotechnology across Arctic countries, research in relation to biotechnology based on Arctic genetic resources concentrates on five main areas. These areas are:

(i) Enzymes for use in a range of industrial processes including food technology;

(ii) Bioremediation and other pollution control technologies;

(iii) Anti-freeze proteins for use in food technology;

(iv) Dietary supplements with a particular focus on polyunsaturated fatty acids (PUFAs); and

(v) Pharmaceuticals and other medical uses.

The following discussion highlights some of the key potential or actual uses for biotechnology based on Arctic genetic resources revealed by a survey of published scientific literature and interviews conducted with a number of scientists currently active in this research.

3.2 Enzymes for use in a range of industrial processes including food technology

In a study based on bacteria isolated from sea ice and sea water samples collected from Spitzbergen in the Arctic Ocean, Groudieva et. al highlight the potential role of cold-active enzymes from Arctic bacteria in biotechnology. As the authors note:

> "Cold-active enzymes including proteases, lipases, cellulose and α-amylases produced by Arctic strains may find applications in various industries (food, detergents, etc). The possible applications of enzymes, which are active at low temperature (4°C), are numerous in the food industry and offer many advantages, e.g., risk of contamination is reduced, and flavor is not destroyed at elevated temperatures. In the dairy industry, cold-adapted β-galactosidase will reduce the lactose content of milk at low temperatures. Diverse starch-modifying enzymes, xylanases, and proteases... can be used to reduce dough fermentation time and improve the properties of dough in bakeries. In addition, cold-adapted lipases are of considerable interest as flavor-modifying enzymes in the production of fermented food, cheese manufacture, beer treatment, and biotransformation reactions in fine chemical processes."[45]

Psychrophiles have attracted attention as sources of enzymes for the food industry particularly in the processing of fruit juices and milk.[46] This is due to the increasing "industrial trend to treat foodstuffs under low temperature conditions to avoid spoilage, and changes in taste and nutritional value at ambient temperatures."[47] Cold-active β-galactosidases, for example are used to remove lactose from refrigerated milk at low temperature so it can be consumed by people who are lactose intolerant.[48]

Proteases from psychrophiles are also used extensively in the food industry for the treatment of beer, in bakeries and in the accelerated maturing of cheese.[49]

There are several examples of research projects seeking to identify lead candidates for possible new enzymes sourced from Arctic biota. For example as noted in a paper previously published as part of the current research[50], in Greenland researchers from the University of Copenhagen have conducted research on possible applications of alkaliphilic enzymes found in microbes from ikaite tufa columns located in the Ikka Fjord in South West Greenland. Microbes with potential in the development of novel biotechnology isolated from the cold alkaline environment of the Ikka Fjord have been identified in the course of that research.[51]

Several companies have expressed interest in this research. One of those companies is Arla Foods a Danish company with interests in milk based products.[52] Arla Foods was a formal participant in a project with Danish researchers on both cold active enzymes and stable enzymes for use in various dairy processes. Arla Foods has also been involved in a research project that aims to develop new peptides using milk proteins cleaved with cold-active proteases from Arctic microorganisms.[53]

Enzymes have been used as processing aids in various food related industries for many years.[54] Ezymatic methods constitute an important and essential part of processes used by modern food industries.[55] Marine enzymes including those from fish in particular offer a wide range of unique applications especially useful in the processing of fish and other food stuffs, some of which are shown in Table 1 below. These possible uses also offer potential environmental benefits. It is widely recognised that marine processing by-products are under utilised often ending up as waste. But the potential applications of proteins, lipids, chitin and minerals in marine bioprocessing leftovers now offer new possible by-products to screen for bioactive compounds with potential applications in a wide range of industries.[56] Greater utilisation of such by-products thus offers potential for more sustainable use of marine biodiversity.

Table 1: Application of enzymes from fish and other aquatic invertebrates[57]

Area of Application	Examples
Selective tissue degradation	Deskining of fish Purification of fish roe- 'caviar production' Removal of membrane from cod liver Removal of exoskeleton from shellfish Production of salted cod swim bladder
Fermentation and curing of fish	Production of fish sauce Production of fish silage Production of 'maatjes herring'
Production of hydrolyzed products	Fish protein hydrolysate Flavour compounds
Extraction of pigments	Enzymatic recovery of pigments from shellfish waste
Coagulation of protein	Application of chymosin as a rennet substitute in cheese manufacturing Removal of oxidized flavour of milk
Waste management	Ezymatic treatment of stickwater
Other potential applications	Meat tenderizing Enzymatic extraction of fish oil from raw material Gene cloning technology Antibacterial enzymes Anti-oxidative enzymes Production of ω-3 fatty acid concentrates

One Norwegian company, Biotec Pharmacon ASA (See Table 3) has been particularly active in research and development of cold adapted enzymes from fishery by-products. Based in Trømso in Northern Norway this company has developed a range of enzymes including shrimp alkaline phosphatase, cod uracil-DNA glycosylase, lysozyme from Arctic scallops (for the hydrolysation of proteins, production of caviar and descaling of fish) and an enzyme for the efficient skinning of squid.[58] GE Healthcare (formerly Amersham Biosciences) also markets Shrimp Alkaline Phosphatase and Shrimp Deoxyribonnuclease sourced from the Arctic shrimp *Pandalus borealis* (See Table 3).

In a study published in 2001 Gildberg[59] highlighted the potential use of fish by-products from male Arctic capelin (*Mallotus villosus* a small Arctic pelagic species found in the Barents Sea) and Atlantic cod intestines as raw materials for the production of high value fish sauce for human consumption.

Enzymes and other biomolecules isolated from psychrophiles such as amylases, proteases and lipases also have potential uses as polymer degrading agents in detergents and dehydrongenases for use as biosensors.[60] The use of enzymes from psychrophiles in detergents is of increasing interest because of the reductions in energy consumption and costs that are associated with using detergents at lower washing temperatures.[61] Esterases and lipases are used in a broad range of industrial applications such as chemical processing, detergent, paper manufacturing, cosmetics and pharmaceutical processing.[62] In a study published in 2007 Kim et. al highlight research relating to esterases and lipases on samples isolated, inter alia, from the Barents Sea North of Russia.[63]

3.3 Bioremediation and other pollution control technologies

Human activities in the Arctic often involve the use of petroleum hydrocarbons (eg diesel or aviation fuel) for power generation, heating and operation of vehicles, aircraft and ships.[64] Accidental spills and past waste disposal practices has resulted in petroleum contamination especially around settlements such as scientific bases, military bases and mining sites in the Arctic.[65] Contamination by polychlorinated biphenyls or PCBs is also a major problem at military bases in the Arctic.[66]

Numerous Arctic sites have been contaminated with hydrocarbon fuels.[67] As one recent study notes

> "With increasing attention towards the preservation of the environment, aboriginal land claim settlements and decommissioning of former military sites, effective and economical means to clean up hydro-carbon contaminated Arctic sites are increasingly needed."[68]

A number of studies have shown that cold-adapted microorganisms show potential for the low-temperature biodegradation of hydrocarbons.[69] This method of bioremediation has several advantages over other available methods. As Eriksson et. al have noted biological treatment of contaminated soil is, when optimized properly, far more cost efficient than traditional methods such as incineration, storage, or concentration.[70] Given the existence of contamination by diesel fuel and other hydrocarbons at a number of existing and former military sites in Canada, the USA, Russia and elsewhere in the Arctic bioremediation using cold-adapted microorganisms clearly offers beneficial new solutions to environmental problems.[71]

Bioremediation, or the use of microorganisms or microbial processes to detoxify and degrade environmental contaminants is a major method employed in the restoration of oil-polluted soils and waters.[72] Since Polar Regions are remote many studies on bioremediation in the Arctic and Antarctica have focussed on remediation of contaminated soils on or near the site of contamination.[73]

In 2001 Mohn et. al[74] published a study on bioremediation of two military radar sites at Komakuk Beach in the Northwest Territories and Cambridge Bay, Yukon Territory in Canada. This study demonstrated the feasibility of bioremediation of hydrocarbon contaminated soils at these sites.[75] In a similar study published in 2002 Thomassin-Lacroix et. al[76] demonstrated the possible bioremediation of weathered diesel fuel in Arctic soil at low temperature on Ellesmere Island, Nunavut, Canada.

At many of these sites scientists have observed naturally occurring microorganisms capable of degrading hydrocarbon spills.[77] There are numerous examples of research on the potential use of these microbes in bioremediation especially in Canada, Finland and Russia (on Russia in particular see Box 2 below). For example, one study of bioremediation of hydrocarbon contaminated soils from the Canadian Forces Station-Alert in Nunavut showed that these degraded soils contained a number of cold adapted micororganisms capable of degrading hydrocarbon contamination in the soil.[78]

In a study published in 2000 Huston et.al highlight the potential of enzymes found in psychrophilic bacteria from sea ice sampled on the coast of Greenland and the Chukchi Sea for use in bioremediation.[79] In a study published in 2005 Deppe et. al[80] highlighted the potential of psychrotolerant microorganisms isolated from Arctic sea ice and sea water from Svalbard to degrade crude oil.

Researchers at the Department of Natural Resource Sciences at McGill University in Canada are involved in research examining the microbial biodiversity and ecology of the Canadian Arctic.[81] Using both classical microbiology and novel genomics-based molecular techniques for studying microbial communities this research includes investigation of possible biotechnological applications of these microorganisms.[82] A second initiative is examining the pollutant degrading capabilities of cold-adapted microorganisms, which may have applications in bioremediation in cold climates.[83] This research includes examination of the physiology, genetics, and ecology of degradative, cold-adapted bacteria and the utilization of this knowledge for decontaminating polluted sites in Northern Canada.[84] The data obtained from both these areas of research is being used to develop and validate environmental microarrays (phylogenetic and functional DNA chips) specific for characterizing and monitoring polar microbial communities.[85]

In Finland, the KAIRA[86] project was carried out by Finnish Forest Research Institute (Metla) from 2004-2007 with considerable support from the mining industry.[87] The mining sector is important to the economy of Northern Finland.[88] It uses a considerable amount of nitrogen-based explosives and these are a major source of ammonia and nitrate in mine waters, much of which flows into surrounding streams and water bodies often causing eutrophication.[89] The aim of the KAIRA project was to develop different treatment processes for the effective removal of total nitrogen in mine waters at low temperature.[90] Focusing on research on microbes sourced from Svalbard and Northern Arctic Finland, this ongoing commercially focused research could potentially have wide application in the mining industry throughout the Arctic and in other cold climates.

Funding organisations, research partners, mine sites and industry sectors involved in the KAIRA project included:

- the European Union Regional Development Fund;
- Tekes Finnish Funding Agency for Technology and Innovations;
- Outokumpu Chrome Oy, Kemi Mine (chromium);
- ScanMining Oy, Pahtavaara Mine (gold);
- Kemphos Oy, Siilinjärvi Mine (phosphorus);
- Agnico-Eagle Finland, Kittilä Mine (Suurikuusikko, gold);
- Anglo American Exploration B.V. plc. (prospecting);
- Scandinavian Gold Prospecting Ab (Kevitsa, PGM and nickel);
- Oy Forcit Ab (explosives);
- Sarlin Hydor Oy (process automation);
- Tekno-Forest Oy (process water treatment); and
- the Geological Survey of Finland, (Mineral processing).[91]

3.4 Anti-freeze proteins for use in food technology

In nature many organisms, including those of the Arctic, are exposed to freezing temperatures and have developed ways to adapt to life at sub zero temperatures.[92] For many organisms this adaptation is made possible by the presence of anti-freeze proteins in their blood.[93] These anti-freeze proteins have been found in a wide variety of fish, plants and animals.

Both Arctic and Antarctic fish are known to generate high levels of anti-freeze proteins as a way to adapt to thermal hystersis and the prevention of ice formation in their bodies.[94] In a study published in 1995 Griffith and Ewart highlight more than 17 species of North Atlantic fish species alone in which anti-freeze proteins have been found, including the Ocean Pout (See Box 3) and Greenland Cod.[95]

BOX 2: RUSSIAN FEDERATION, UNEP, GEF PILOT PROJECT ON DEVELOPMENT OF BIOTECHNOLOGY BASED ON USE OF BROWN ALGAE FOR CLEANING UP MARINE WATER FROM OIL AND OTHER POLLUTANTS IN THE ARCTIC

One of the most significant research uses of biotechnology based on Arctic genetic resources developed to date is the joint Russian Federation, United Nations Environment Program (UNEP) and Global Environment Facility (GEF) *Pilot Project-Marine Arctic Environment Clean-Up by Setting up Brown Algae Shelter Zones Around Pollution Sources* (the '*Biotechnology Pilot Project*').

In November 2005 the Russian Federation in partnership with UNEP, the GEF and other partners launched a joint project titled "*Russian Federation-Support to the National Programme of Action for the Protection of the Arctic Marine Environment*." Major outcomes of the Project will include a nationally approved Strategic Action Programme to address damage and threats to the Arctic environment from land-based activities in the Russian Federation; direct and related improvements to environmental protection (legislative, regulatory and institutional and technical capacity) within the Russian Federation; the completion of ten pre-investment studies to determine the highest priority and tractable interventions to correct or prevent transboundary impacts of land-based activities; and three categories of demonstration projects dealing respectively with marine environmental clean up (ie the *Biotechnology Pilot Project*), the transfer of two decommissioned military bases to civilian control, and involving indigenous peoples in environmental and resource management.

The results are intended to benefit the international Arctic environment, particularly the Arctic Ocean basin and its shelf seas, and contribute to two principal international agreements: the Arctic Environmental Protection Strategy (AEPS); and the Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities (GPA) as implemented in the Arctic Region through the Regional Programme of Action for the Protection of the Arctic Marine Environment from Land- based Activities (RPA) and the Arctic Council Plan of Action to Eliminate Pollution of the Arctic (ACAP).

The *Biotechnology Pilot Project* centres on the use of biotechnology derived from several species of marine algae and bacteria from the Arctic which act as a symbiotic association bio-filter plantation which absorbs oil and other hydrocarbon based pollution. The species involved include:

- Devils apron (*Laminaria saccharina*) an algae species common to the Arctic sea, and already widely used commercially in the manufacture of alginate and mannitol and other compounds used in biotechnology including health care;

- Bladder wrack (*Fucus vesiculosis*) which is an algae which demonstrates incredible resistance to external forces: it survives low salinity, sustains exposure to high doses of ultraviolet radiation and sunlight for long periods of time, survives high waves and tidal processes as well as long periods without sunlight, and can survive high levels of contamination by oil; and

- Oil oxidizing bacteria occurring in sublittoral and littoral waters in the Barents Sea including 7 genera of hydrocarbon-oxidizing microorganisms (*Pseudomanas*, *Proteus*, *Micrococcus*, *Arthrobacter*, *Corynebacterium*, *Mycobacterium*, and *Rohdocccus*).

This bio-filter plantation of algae operates in three ways: Firstly the algae plantation prevents oil slicks from spreading acting as a slick bar. At the same time the algae absorbs petroleum hydrocarbons, while the algae/oil oxidizing bacteria association facilitates the decay of the polluting oil products and facilitates growth of the algae. This technology has the potential to capture and degrade tens or even hundreds of thousands of tons of crude oil.

The *Biotechnology Pilot Project*'s key outputs involve demonstrating the potential biotechnology offers in absorbing and capturing petroleum hydrocarbons, its cost effectiveness, algae plantation standard design and management methods that can be replicated in the basins of the Arctic Ocean and its seas, and hence assist in reducing the impact of pollution associated with oil and gas exploration and exploitation in the Arctic.

Phase 1 of the *Biotechnology Pilot Project* involving a feasibility study and initial pilot site selection was completed in September-October 2007 and the results of this phase are currently being assessed.

Source: UNEP/GEF Russian Federation-Support for the National Programme of Action for the Protection of the Arctic Marine Environment web site and associated project documents available thereon[96]

The properties of anti-freeze proteins isolated from such species have a wide number of possible applications in biotechnology including:

- enhancing the cold storage and cryopreservation of cells and tissue;
- use as ice nucleators to inhibit recrystalisation of ice during freezing and thawing with application in the cold storage of food;
- preservation of food texture and flavour in frozen food; and
- reduction or prevention of microbial contamination of frozen food.[97]

Their use in food manufacture and storage is of particular interest with major food manufacturers such as Unilever already investing large sums in R&D in relation to their applications in ice cream manufacture and other potential applications. See Box 3 below for further details. While the use of anti-freeze proteins from fish in ice cream by Unilever has been controversial it is worth noting that anti-freeze proteins are already present in a wide range of organisms already consumed as part of the human diet including fish, carrots, cabbage and Brussel's sprouts.[98]

3.5 Dietary supplements with a particular focus on polyunsaturated fatty acids

Fish oil is well regarded as an excellent source of long-chain polyunsaturated fatty acids (PUFA) especially omega 3 fatty acids, and has been linked to the promotion of good health and the fight against numerous diseases.[99] In a recent survey of the published literature Kim and Mendis[100] noted the following potential health benefits of omega 3 fatty acids mentioned in the literature included:

- prevention of atherosclerosis;
- protection against arrhythmias;
- reduced blood pressure;
- benefits for patients with diabetes;
- treatment of manic-depressive illness;
- reduced symptoms in asthma patients;
- protection against chronic obstructive pulmonary diseases;
- alleviating symptoms of cystic fibrosis;
- improving the survival of cancer patients; and
- preventing relapses in patients with Crohn's disease.

BOX 3: UNILEVER USE OF ANTI-FREEZE PROTEINS FROM THE ARCTIC OCEAN POUT IN MAKING ICE CREAM

Unilever, one of the world's largest food manufacturers has developed a low fat ice cream containing an anti-freeze protein from the ocean pout (*macrozoacres americanus*), an eel like fish commonly found of the northeast coast of North America and the Arctic Ocean.

For several years Unilever has invested in R&D in relation to the use of anti-freeze proteins to control ice formation and structure for use in edible ices such as ice cream. The use of the these anti-freeze proteins enables edible ices to be produced which are lower in fat, and/or lower in added sugar and/or with increased fruit content. Thus making for a healthier edible ice.

This development is the result of a novel technique of genetic modification involving the isolation of a gene from a protein from the blood of the ocean pout which has in turn been inserted into the genome of a genetically modified strain of food grade bakers yeast *Saccharomyces cerevisiae* (VW strain).

The benefit of the use of this technique is that it removes the need for anti-freeze proteins to be harvested directly from fish. This is a significant environmental advantage in an era where many fish stocks are over harvested and some on the verge of extinction.

On the down side though critics of the technology have raised concerns about the use of anti-freeze proteins from fish in food that might be eaten by people with allergies to fish and seafood.

While such criticisms have been made, regulatory approval for the use of this technology has already been granted by the US Food and Drug Administration, and by regulators in Australia, New Zealand, Chile, Indonesia, Mexico and the Phillipines. Unilever also recently lodged an application for approval for use of the technology under the European Communities Regulation (EC) No 258/97 Concerning Novel Foods and Novel Food Ingredients for use in ice cream, sorbets, frozen deserts and other edible ice products. This application was provisionally approved on 30 July 2007.

The ice cream will be marketed under the Wall's, Magnum, Carte D'Or and Ben & Jerry's trademarks.

Source: Food Standards Agency United Kingdom and New York Times.[101]

The extraction and manufacturing of fish oil rich in omega 3 fatty acids is already an established industry that has been operating in several Arctic countries for over a century. Several companies mentioned in Table 3 are already well established in this industry.

PUFA have traditionally been obtained from fish oil (and to a lesser extent from algal oils).[102] But PUFA obtained from fish oil does come with several problems such as an undesirable odor, difficulties of large scale purification and concerns about ensuring ongoing supply as fish stocks continue to diminish worldwide.[103] Although a number of the companies mentioned in Table 3 have invested in considerable R & D to address some of these issues.

Recently scientists have found an alternative source of PUFA in Antarctic marine bacteria, mainly in species of *Shewanella* and *Colwellia*.[104] Development of economically viable technologies for the production of microbial PUFA for use in aquaculture, livestock and human diets is the focus of considerable research efforts worldwide.[105] Although a significant focus of research it is a costly and time consuming process to achieve marketable products.[106]

3.6 Pharmaceuticals and other medical uses

There is evidence of research and development interest in the potential of Arctic genetic resources in new leads for pharmaceuticals and other medical uses.

The *Armi Project* co-ordinated by the Finnish Forest Research Institute (Metla) ran from 2001 to 2004 and isolated some 600 strains of microbes from boreal and Arctic environments in soil sediment, stream water, snow, lichen and moss from Lapland in Northern Arctic Finland and Svalbard in the Norwegian Arctic. As well as seeking to identify possible leads for new developments in environmental biotechnology, wastewater treatment and novel enzymes for use in food biotechnology this research also examined possible pharmaceutical applications.[107] Initial results from work on possible pharmaceutical applications were quite promising. For example, several of the *Pseudomonas* bacterial strains isolated from soil samples from Lapland showed anti-microbial characteristics with potential for treating ailments like sore throats caused by *streptococci*.[108] A European pharmaceuticals company has subsequently bought the rights to start screening the collection of bacterial strains collected as part of the *Armi* research for anti-cancer drug candidates.[109]

One of the most surprising examples of Arctic biodiversity being studied for medical purposes is the Arctic ground squirrel (*Spermophilus parryii*) and the potential it offers for new treatments for Ischemia. Ischemia or restrictions in blood flow are a major medical problem with many causes that can often result in death. As one recent publication observes

> "When the blood circulation is arrested due to sudden cardiac arrest or impending circulatory arrest from trauma, it is not merely a localized 'big heart attack' or a localized 'big stroke or both at the same time. It is a more general insult to every organ, including the heart and the brain, together with complex adaptive responses at levels of cells tissues, organs and ultimately the organism."[110]

Research into the physiology of hibernation by animals such as the Arctic ground squirrel offers new insights into potential treatments for Ischemia. As Becker et.al have observed

> "The physiology of hibernation offers insights into what may become one of the most important breakthroughs in the treatment of global ischemia. In settings in which oxygen delivery or availability is reduced, ischemic injury is minimized or prevented by reducing the oxygen need both locally and systemically. During hibernation, the heart rate decreases to as little as 5% of normal, levels that would be lethal during active states. Remarkably, no damage occurs during this prolonged "ischemic" state, nor does the cardiac rhythm deteriorate into ventricular fibrillation. After arousal and restoration of normal blood flows, the "reperfused" organs and tissue show no evidence of ischemic injury...The value of hibernation in the presence of shock has not as yet been adequately explored and will require research before clinical trials in the setting of trauma can begin. The possibility exists that therapeutically induced hibernation may also minimize both ischemic and reperfusion injuries. The development of transient therapeutic hibernation or "stasis" state wherein injury to human organs could be prevented during ischemic states may have a profound benefit after major injuries associated with critical reductions in vital organ perfusion."[111]

Part of the explanation of how the Arctic ground squirrel survives hibernation may lie in the presence of certain enzymes or proteins in its blood stream, although the exact reason is still unknown.[112] Further research on this animal may offer clues for treating or preventing stroke-related brain injury in humans when blood flow transiently reaches the low level typical of hibernation.[113]

At least one company is known to be working on potential development of new drugs from research on the Arctic ground squirrel. See Box 4 below.

3.7 Marine biotechnology with a focus on Arctic genetic resources

Marine biotechnology is the focus of research in several Arctic States. Many of the companies listed in Table 3 are active in marine biotechnology. Of all the Arctic

States, Norway has the most developed and successful marine biotechnology sector that is focused on Arctic genetic resources. Norway has four universities pursuing research into marine biotechnology (in Oslo, Bergen, Trondheim and in the Arctic at Tromsø), several marine research institutes (including the Institute of Marine Research in Bergen and the Norwegian Institute of Fisheries and Aquaculture in Tromsø), several large-scale aquaculture stations (near Bergen, and in Tromsø) and a research station at Ny Ålesund, Spitzbergen.[114] Across industry, universities and other research institutions in Norway in 2003 there were at least 1,600 researchers, scientific personnel and specialist employees engaged in marine research and development.[115] Of the more than 100 biotechnology companies in Norway a significant number of these companies are active in research, development and commercialization of marine biotechnology. Some examples of these companies (not necessarily all focused on the exploitation of Arctic genetic resources) are shown in Table 2.

BOX 4: DEVELOPING NEW DRUGS FROM THE ARCTIC GROUND SQUIRREL

Neuronascent Inc. is a company focused on the discovery and development of therapies for Alzheimer's disease, stroke and depression based on the science of neurogenesis that: reduce the loss of neurons; restore and replace damaged neurons; promote the formation of new neurons; and reverse cognitive loss.

Neuronascent has developed adult neural stem cells derived from the Arctic ground squirrel. The Arctic ground squirrel is the only known mammal capable of lowering its body temperature to below freezing during hibernation. The species tolerates prolonged periods of cerebral blood flow (ischemia) with minimal neural cell death.

Neuronascent researchers are attempting to discover what cellular proteins allow for this tolerance. Small-molecule compounds that act on these identified "protein targets" will then be synthesized. Further research on the stem cell isolated from the Arctic ground squirrel may have potential applications in treating strokes in humans.

Neuronascent has recently granted a worldwide exclusive licence covering the marketing, sale and distribution of adult Arctic ground squirrel neural stem cells for research use to Lifeline Cell Technology LLC a wholly owned subsidiary of International Stem Cell Corporation.

Source: Neuronascent web site.[116]

Unlike the other Nordic countries, Norway is in the unique position of having territorial waters and an exclusive economic zone ('EEZ') that ranges from the relatively cool Northern part of the North Sea/ Western edge of the Skagerrak to the frigid polar areas surrounding Svalbard, Jan Mayer Land and the Western part of the Barents Sea.[117] Having access to these diverse marine habitats, a maritime and marine heritage and existing strengths in marine biotechnology has led the Norwegian Government to adopt several policy initiatives focused on further expanding Norway's marine biotechnology industry.[118]

In 2002, the Norwegian Government established a national plan for Functional genomics (the FUGE Programme), which aims to establish "the research basis needed to promote further development of the aquaculture industry, optimal utilization of marine resources, and the creation of a biomarine industrial cluster in Norway."[119]

The exploitation of Arctic genetic resources figure prominently in the FUGE programme. The initial plan for the FUGE Program noted

> "It is of particular interest for Norway to conduct bioprospecting in the Arctic regions, where aquatic organisms have adapted to life under extreme conditions since the beginning of time, but there may also be reason to extend this activity to land-based organisms."[120]

The reasons for scientific and commercial interest in bioprospecting in the Arctic marine environment are much the same as for Antarctica. As one of the leading researcher's active in this field has noted

> "As a marine environment, the high Arctic is unparalleled with respect to its combination of temperature and light regimes. This implies evolution of a variety of organisms with unique physiological and biochemical adaptations, and with correspondingly good prospects for finding novel lead compounds and bioactives."[121]

By 2003, approximately €17.5 million had been committed by the Norwegian Government to fund the FUGE programme.[122] Bioprospecting in northern Norwegian waters and sub-Arctic waters has included looking for enzymes, enzyme inhibiters, antioxidants, and immune modulators from species such as sea anemones, starfish, sponges, sea urchins, and spider crabs.[123]

The Mabcent Initiative (See Box 5) is a significant element of the FUGE programme bringing together both industry and academic researchers interested in the biotechnology potential of the marine genetic resources of the Arctic.

3.8 International co-operation in relation to Arctic genetic resources

Although research on the biotechnology potential of Arctic genetic resources is largely occurring in the sovereign territory or waters of the Arctic States, the pattern of research activities in the Arctic and in particular around the Norwegian territory of Svalbard mirrors patterns of research activity in Antarctica. That is to say that there is a strong emphasis on collaborative research by teams of international researchers in the Arctic. For example, there are a number of foreign research stations based in Svalbard. These include the British research station Harland House, the Italian research station Dirigibile Italia, the Korean Arctic Station at Ny-Ålesund, the Chinese Yellow River research station, the Polish Polar research Station at Polar Bear Bay (Isbjørnhamna), Hornsund fjord and the Russian research facility at the Barentsburg Observatory. This is in addition to the numerous ship-based researchers who pass through this area each year.

As in Antarctica, research at these stations covers a wide range of scientific interests. However, Norwegian researchers are not the only ones interested in bioprospecting in and around Svalbard and a number of these research stations are currently engaged in research that might be characterised as bioprospecting. For example, the Korean Polar Research Institute has carried out research on bioactive metabolites from Arctic organisms with potential for developing new treatments for leukemia, as well as research on Arctic micro-organisms with potential in developing new anti-biotics and for developing new industrial enzymes.[124] Similarly Korean researchers at the Dasan Station on Svalbard have carried out research on the development of novel substances from Arctic Biota involving the isolation and identification of the Arctic microorganisms around Kongsfjorden.[125]

Polish researchers have carried out research on the biotechnology potential of micro-organisms in soil and snow from Svalbard.[126] Similarly in 2003 researchers from the Fraunhofer Institute for Biomedical Engineering IMBT in Germany examined cold loving bacteria from Arctic snowfields for possible enzymes with uses in temperature sensitive processes such as milk processing.[127] Researchers from the Fraunhofer Institute have also conducted research on snow and soil algae from Arctic and Antarctic environments as well as screening several algal strains for their suitability for an industrial scale production of carotinoids and other secondary metabolites such as vitamin E in photobioreactors. [128]

From 2007, researchers from India will also explore the biotechnology potential of microbes from the Spitsbergen archipelago.[129]

BOX 5: THE MABCENT INITIATIVE AND BIOPROSPECTING IN THE NORWEGIAN ARCTIC

One of the main centres for bioprospecting activities in the Norwegian Arctic is based in Tromsø. The MabCent initiative is a newly launched consortium between the Norwegian Research Council, the University of Tromsø and four Norwegian biotechnology companies: Lytix Biopharma; ProBio Group Holdings; Biotec Pharmacon ASA; and Pronova Biopharma (previously known as Pronova Biocare) (See Table 3).[130]

MabCent is one of 14 Centres for Research-based innovation that have been established in Norway and it aims to 'bring marine bioactives from the deep waters of the Arctic to the pharmaceutical and other high value markets'.[131] This research will be aided by the technology platforms of MarBank (a national Marine Biobank), MarBio (a high throughput screening program), NoStruct (the Norwegian Structural biology Center), SmallSruct (a research programme on proteins and small molecules) and the FUGE programme mentioned above.[132]

A total of NOK 180 million (approximately US$32,560,000) has been committed to the MabCent initiative by the Norwegian Research Council, the University of Tromsø and the associated biotechnology companies. Approximately 25% of this funding has been provided by the commercial partners.[133]

The MabCent consortium will 'focus on the discovery of molecules with novel properties extracted from cold adapted algae, bacteria and benthic ... invertebrates, including crustaceans, molluscs, annelids and sponges'.[134] The main research interest lies in the potential development of pharmaceuticals in the broad areas of antibiotics, anti-cancer drugs, anti-inflamatory drugs, diabetes and obesity, anti-oxidents and immunostimulants.[135] Biological samples for these activities are being sampled from the waters of the northern Norwegian coast and the waters north of Svalbard.[136]

During the International Polar Year (IPY) there are also a number of collaborative scientific research projects underway that include research on the biotechnology potential of the Arctic. The IPY is a large scientific research program focussed on the Arctic and Antarctica that runs from March 2007 to March 2009.[137] This is the fourth polar year, following those in 1882-3, 1932-3, and 1957-8. The IPY involves over 200 scientific research project around the world, with thousands of scientists from over 60 nations examining a wide range of physical, biological and social topics.

During the IPY the Project on Polar microbial diversity: exploration, function and exploitation or POMIDIV is examining, inter alia, the biotechnology potential of microorganisms from both the Arctic and Antarctica for use in biotechnology including potential for new enzymes and compounds with pharmaceutical applications.[138] The Arctic component of this research will focus on areas including northern Ellesmere Island in Canada, the Arctic Sea, Greenland and Svalbard.[139] Researchers involved in this project include researchers from Belgium, Canada, the United Kingdom and Australia.[140]

Another example of an IPY project worth noting is the Polar Aquatic Microbial Project or PAME. This project also touches in part on the biotechnology potential of the Arctic. PAME is major collaborative project involving researchers from Norway, Canada, Italy, Russia, Denmark, The Netherlands, Sweden, France, the United Kingdom, Germany, Spain and the USA. PAME is focussing on the role of microorganisms in the marine environment of the Arctic and Antarctica, with a particular focus on their activity with respect to climate and global environmental change. Although biotechnology is not the main research focus of this project one of its outputs will be data that

> "will be indispensable for a knowledge based management of natural resourses and pollution issues in polar waters and for assessing the potential of microbial bioremediation. Moreover, the knowledge will also provide a basis for bio-exploitation of polar microorganisms and biomolecules of use to mankind [sic]."[141]

4. Companies active in biotechnology developed from Arctic genetic resources

Fourty three companies are involved in R&D and or sale of products derived from or based on the genetic resources of the Arctic. Details of these companies including their areas of R&D interest and (where applicable) products marketed derived from or based on the genetic resources of the Arctic are presented in Table 3. This data is based on information contained on each companies web site or from information obtained in interviews with representatives of several of these companies.

More than half of these companies are based in North America (ie the USA and Canada). A significant number of the companies are also based in the Nordic countries of Iceland and Norway, and to a lesser extent, Finland, Sweden, Denmark and the United Kingdom. No companies were identified in Russia.

The activities of these companies fall into 9 broad categories of specialisation. In many cases companies specify a R & D or commercial focus in more than one category. As much of this data is based on information sourced from company web sites which only occasionally identified a dominant R&D focus it has not been possible to identify a dominant R&D focus for many companies. In some cases companies actually specify a R&D, focus in three or more categories. For example, based on information on the web site of Aquapharm Biodiscovery that companies R&D focus fits into four different categories. The figures presented below therefore have to be approached with a degree of caution. They should not be viewed as definitive, but rather suggestive of possible trends.

The categories (and number of companies with interest in each category)[142] include: nutraceuticals, including dietary supplements and other health products (13 companies); medicines and pharmaceuticals (15 companies); food technology (7 companies); anti-freeze proteins (3 companies), enzymes (10 companies); cosmetics and skin care products (6 companies); products with life science research applications (3 companies); research based service companies (2 companies).

Even though this data should be approached with a degree of caution, one of the major trends evident in this data is a strong focus on health care related R&D and products. In particular there are a large number of companies falling within the broad categories of nutraceuticals, including dietary supplements and other health products and medicines and pharmaceuticals. In that regard it is worth noting that only three companies fall within both categories.

Other dominant areas of R&D and product focus include enzymes, food technology and cosmetics and skin care products.

5. Patents, Arctic genetic resources and biotechnology

A desk top search of the European[143] and US patent databases[144] has identified thirty one patents and or patent applications in relation to inventions based on or derived from the genetic resources of the Arctic. Details of these patents/patent applications are set out in Table 4 at the end of this report. As shown below in Figure 1 in general terms these can be grouped into seven broad categories as follows*:

(1) *Enzymes with life science research applications in DNA research*: This category constitutes 34% of the patents/patent applications identified;

(2) *Medicines and pharmaceuticals:* This category constitutes 23% of patents/patent applications identified;

(3) *Cosmetics and skin care:* This category constitutes 10% of patents/patent applications identified;

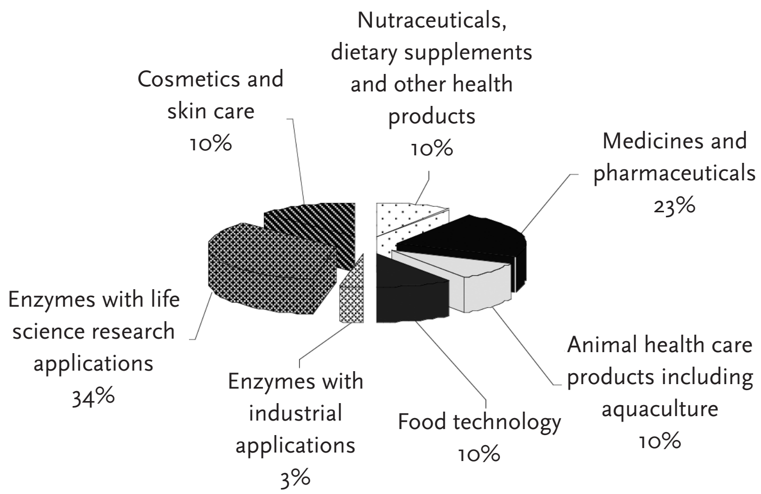
(4) *Nutraceuticals, dietary supplements and other health products:* This category constitutes 10% of patents/patent applications identified;

(5) *Animal health products including aquaculture*: This category constitutes 10% of patents/patent applications identified;

(6) *Food technology:* This category also constitutes 10% of patents/patent applications identified;

(7) *Enzymes with industrial applications:* This category constitutes 3% of patents identified.

Figure 1: Patents/patent applications based on Arctic genetic resources by category



Some of the patents identified arguably fit into more than one broad category as the claims made in the patent/patent application often identified more than one potential use for the invention. For the purposes of this study though, after examination of each patent, a dominant category was selected and the patent allocated to that category. Thus for example most of the patents in the *Enzymes with life science research applications* category also listed potential industrial and commercial applications in the claims made in the patent/patent application and could have also been included in the *Enzymes with industrial applications* category. But a review of these patents suggest the former, rather than the later, is the dominant theme of the patent and accordingly they were allocated to the *Enzymes with life science research applications*. Thus the allocations to specific categories presented in Figure 1 are indicative of general trends only.

Figure 2 below highlights that the major jurisdiction for patents and or patent applications in relation to inventions based on or derived from the genetic resources of the Arctic is the USA (66%) and to a lesser extent European jurisdictions (combined total 18%). One point worth noting is that 10% of these patents/patent applications have been filed in Russia a jurisdiction which does not usually figure prominently in patent figures. This exceeds the number of patents/patent applications filed in Japan. However, given the small sample size it is unclear if this discrepancy is of significance. No patents were identified in the Arctic jurisdictions of Canada, Sweden, or Denmark.

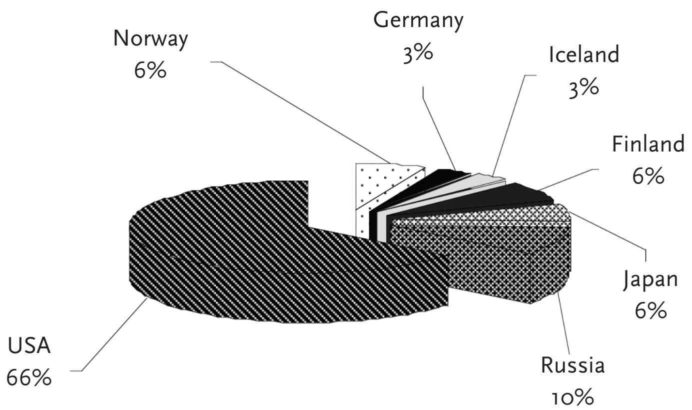
One interesting aspect of the figures is that contrary to trends observed in company R&D and product focus noted above, the most significant proportion of the patents/ patent applications relate to inventions relating to enzymes (both in the *Enzymes with life science*

*Given the small sample size these figures should be approached with caution indicative only of general trends.

research applications category (34%) and *Enzymes with industrial applications* category (3%). While health related patent/patent applications in the categories of *Medicines and pharmaceuticals* (23%) and *Nutraceuticals, dietary supplements and other health products (10%)* are of less significance than data on companies R&D and product focus above would suggest.

There are a number of possible explanations for this. Firstly the *Nutraceuticals, dietary supplements and other health products* category may include products that cannot be the subject of a patent because they do not meet the criteria of inventiveness or novelty required for a patent to be granted. For example, in the case of products based on Omega 3 fatty acids such as fish oils the purported health benefits of fish oils have been known for generations. Given the significant body of prior knowledge in this area patents are less likely to be granted. This may not always be the case and new patentable inventions may still be possible even with a significant body of existing knowledge, but this could be a partial explanation.

Figure 2: Patents and patent applications by jurisdiction



A further explanation may lie in the cost associated with filing and maintaining a patent. The World Intellectual Property Organisation notes that these costs fall into four broad categories:

> "Firstly, the costs relating to the application fees and other prosecution fees paid to the national or regional patent offices. Such costs may vary widely from country to country ...Secondly, the costs relating to patent attorneys/agents who assist in drafting the patent application. While the use of a patent attorney/agent is usually optional (unless the applicant is not residing in the country and the law requires that he [sic] be represented by an attorney or agent admitted in the country), it is generally advisable to seek legal advice when drafting a patent document. Patent attorney fees will vary significantly from country to country. Thirdly, costs of translation. Such costs are only relevant when seeking IP protection in foreign countries whose official language is different from the language in which the application has been prepared and may prove to be high, especially for highly technical patent applications. Fourthly, the cost of maintaining applications and patents through payments to the patent office. Such fees are usually paid at regular intervals (e.g. every year or once every five years) in order to maintain the application or the patent. Protecting patents for the entire term of protection (in general, 20 years) in various countries may prove an expensive undertaking, also taking into account that annual maintenance fees are usually increasing the longer the protection is maintained. Such costs would have to be compared to the wide range of benefits that could derive there from."[145]

Thus although fees vary from jurisdiction to jurisdiction, for smaller companies the benefits of patenting each and every new invention developed in the course of R&D may not justify the cost. Many of the companies identified in the *Nutraceuticals, dietary supplements and other health products* category in this study are small companies so this may in part offer an explanation for the absence of patents in this field. This is also consistent with anecdotal comments made by several scientists and one of the company representatives interviewed for the purposes of this research who indicated that the cost of patenting often means patenting of inventions is not a high priority.

Thus while as a general rule patents in certain circumstances may be viewed as a fair proxy of the level of commercial interest in relation to particular fields of biotechnology[146], data on patents should be approached with caution as some companies simply do not bother with the patent system as they view patenting as an expensive process offering little return on investment. Commercial interest in Arctic genetic resources may therefore be much larger than analysis of patent data suggests.

6. Conclusion and implications for Antarctica and beyond

This report has examined the extent and nature of bioprospecting in the Arctic. It is clear from the data presented in this report that there is significant interest in the biotechnology potential of Arctic biodiversity. In many cases this potential has moved beyond the research of the academic community to industry. In fact given the number of companies involved in research or current exploitation of biotechnology based on the genetic resources of the Arctic one clear conclusion is that this industry, in various forms, is well established.

It is also clear that biotechnology based on the genetic resources of the Arctic covers several key areas including enzymes (including those used in life science research and a range of industrial applications), anti-freeze proteins, bioremediation, pharmaceuticals, nutraceuticals and dietary supplements, cosmetics and other health care applications. There is also a significant focus on marine biotechnology R&D.

In many respects therefore the areas of interest for developments in biotechnology match those of Antarctica, especially in the areas of enzymes, anti-freeze proteins and bioremediation.

One of the outstanding questions in the debate on bioprospecting in Antarctica is whether commercial interest in Antarctic genetic resources is more than just a momentary diversion from the "pure science" [sic] upon which the framework of Antarctic governance is built?[147] The findings presented in this report lend considerable support to the argument that it is not. The overwhelming conclusion that can be reached from the analysis of the data presented in this report is that R&D in relation to the biotechnology potential of genetic resources of the Arctic and the actual commercialisation of such research is occurring on a significant and ongoing basis.

Arguably one might also expect to see similar developments in relation to biotechnology based on the genetic resources of Antarctica. Of course such an argument is by no means conclusive. One needs to approach translation of the Arctic experience to Antarctica with some caution. As noted at the beginning of this report there are significant differences between the Arctic and Antarctica and these should not be underestimated. Although not an issue examined in length in the current research, the existence of considerable infrastructure including major towns and research institutions such as universities in the Arctic may be a significant factor supporting the growth of biotechnology R &D in the Arctic. Similarly the relative ease of access to Arctic biodiversity for research purposes should be contrasted with the logistical difficulties of access to Antarctica.[148]

The isolation of Antarctica's biodiversity from the rest of the world for millions of years should also be contrasted with thousands of years of human settlement in the Arctic. But in part the differences between the biodiversity of Antarctica and the rest of the world is what is driving interest in Antarctica's potential for novel developments in biotechnology. There are many differences between the climate and environment of the Arctic and Anatarctica which in turn are reflected in significant differences in Antarctic and Arctic ecosystems and biodiversity.

Whether bioprospecting and development of biotechnology from Antarctica will ever match that of the Arctic remains to be seen. Nonetheless the existence of established R&D programs and considerable commercial activity based on Arctic genetic resources should not go unnoticed as the international community further considers the implications of the emergence of bioprospecting as a new commercial activity in Antarctica.

Beyond Antarctica the data presented in this report highlights that bioprospecting is also an emerging activity in the Arctic which in turn raises questions about what if any regulatory or policy response this may require. As noted in earlier publications[149], so far only Greenland has adopted a specific regulatory regime to regulate access and benefit sharing in relation to genetic resources in the Arctic region.[150] Norway and Finland are in the process of developing such a regime.[151] Iceland only regulates bioprospecting in relation to microbes isolated from geothermal areas.[152] Sweden and Denmark have determined that for the time being they do not intend to regulate access and benefit sharing with respect to their own genetic resources.[153] Likewise there currently appears to be no regulation in Russia. The USA has not ratified the Convention on Biological Diversity and with the exception of collection of specimens within national parks there is no regulation of bioprospecting at present.[154] In Canada the situation is less clear. At the national level government policy on access and benefit sharing is still under development.[155] Although at the provincial level some aspects of access and benefit sharing are regulated under provincial legislation, but no clear and formal system of regulation yet exists.[156]

At the regional level there has been no consideration of the implications of bioprospecting in the Arctic by the Arctic Council and its working group on Conservation of Arctic Flora and Fauna (CAFF) or by the other main regional co-operation mechanisms associated with the Nordic Council of Ministers.[157] Data presented in this report may serve as a starting point for closer examination of the regulatory implications of bioprospecting in the Arctic by such regional bodies.

The Arctic region also contains significant areas of ocean space in areas beyond national jurisdiction as well as several areas of contested jurisdiction.[158] The status of the genetic resources of marine areas beyond national jurisdiction is emerging as a significant issue in its own right. As noted in an earlier UNU-IAS study[159] in recent years the question of the status of genetic resources of marine areas both within and beyond national jurisdiction has been the focus of diplomatic discussions (directly and indirectly) in no less than five different international institutions and mechanisms including meetings associated with the 1992 Convention on Biological Diversity, the International Seabed Authority, the United Nations Informal Consultative Process on the Law of the Sea, the annual debates of the United Nations General Assembly on Oceans and the Law of the Sea, and more recently, in the deliberations of Ad Hoc Open-ended Informal Working Group to study issues relating to the conservation and sustainable use of marine biological diversity beyond areas of national jurisdiction.

Data on bioprospecting in Arctic ocean space beyond national jurisdiction is clearly relevant to those debates. Unfortunately the present study has little to offer on bioprospecting in Arctic waters in areas beyond national jurisdiction, perhaps other than to state that it is not possible to clearly identify to what extent bioprospecting is occurring in Arctic areas beyond national jurisdiction. Researchers and companies don't clearly articulate where these activities are taking place. Clarity on this issue perhaps awaits further detailed studies.

A complex related and as yet unresolved issue at the core of much of the debate surrounding marine genetic resources which is also relevant in the Arctic context, is the distinction between marine scientific research and bioprospecting. The distinction between marine scientific research and bioprospecting is often blurred, however, and the relationship between these two activities has not yet been clearly defined.[160] As an earlier study by UNU-IAS has noted

> "A common distinction is made between scientific research undertaken for non-commercial purposes, also called "pure scientific research", and commercially –orientated research, also called "applied scientific research. Bioprospecting in the marine environment could also be considered as a form of applied scientific research."[161]

Yet the practical application of these distinctions is incredibly difficult for policy makers. While such distinctions are commonly made there are currently no internationally agreed definitions of the terms marine scientific research and bioprospecting.[162] As the authors of the earlier study mentioned above note

> "Bioprospecting is neither used nor defined in the Convention on Biological Diversity (CBD) or UNCLOS, and the expression seems to cover a broad range of activities. The CBD does not make the distinction between pure and applied research, and only requires Parties to promote and encourage research that contributes to the conservation and the sustainable use of biological diversity in general....As with the term "bioprospecting", there is no internationally-agreed definition of marine scientific research." While UNCLOS provides for a regime of marine scientific research (MSR), it does not define what MSR is. With regard to the right of the coastal States to withhold consent to MSR projects proposed by other States or international organizations in their Exclusive Economic Zone (EEZ) or on their continental shelf, UNCLOS draws a distinction between MSR projects proposed by other States to withhold consent to MSR intended to increase scientific knowledge for the benefit of all humankind, and MSR "of direct significance for the exploration and exploitation of natural resources." The distinction between those two types of research, which equates to pure scientific research for the former and applied research for the latter, is not made with regard to MSR undertaken beyond national jurisdiction."[163]

The provisions of the 1982 United Nations Convention on the Law of the Sea alluded to in the above quote relate primarily to the mineral resources of the EEZ and Continental shelf. However, it is clear that despite the absence of a clear definition marine scientific research has nonetheless been given a special status and is recognised as one of the freedoms of the high seas by both customary international law and the 1982 United Nations Convention on the Law of the Sea in areas beyond national jurisdiction. It is also subject to a specific regime in areas within national jurisdiction within the EEZ and continental shelf.[164]

As debate grows on the need or otherwise for a specific regulatory regime with respect to the commercial use of genetic resources in areas beyond national jurisdiction, including in the Arctic, the lack of clear definitions for marine scientific research and bioprospecting is a key issue that needs to be addressed. If the special status of marine scientific research and scientific research more broadly is to be maintained while at the same time bioprospecting is to be treated as something different, perhaps subject to a totally different and new regulatory regime, then agreed definitions for both will need to be developed.

There are already several definitions of bioprospecting available in both domestic legislation and a range of other international instruments and documents.[165] In that regard as has previously been suggested perhaps suitable elements of a definition of bioprospecting might include recognition that it includes:

> "- systematic search collection, gathering or sampling of biological resources for purposes of commercial or industrial exploitation;
>
> - screening, isolation, characterization of commercially useful compounds;
>
> - testing and trials; and

- further application and development of the isolated compounds for commercial purposes, including large-scale collection, development of mass culture techniques, and conduct of trials for approval for commercial sale."[166]

In examining each of the activities documented in this report it was not always possible to clearly say at a particular point that a particular activity was either scientific research or bioprospecting, perhaps re-enforcing the conclusion that there is no clear transition point from one activity to the other. Nonetheless when one looks back at all of the data presented in this report with hindsight it is possible to say that where products have eventually been commercialised the path to commercialisation has clearly followed the steps suggested by the elements of the definition of bioprospecting mentioned above.

Despite the clarity of hindsight further detailed research on the distinction between marine scientific research and bioprospecting is clearly warranted. Further debate on bioprospecting in the Arctic both within and beyond areas of national jurisdiction will need to take account of the difficulty in clearly defining both activities and considering the regulatory implications of such a distinction. If that debate can be resolved then the Arctic experience may offer yet more valuable lessons for the debate on bioprospecting in Antarctica and in other regions of the world including in ocean space beyond national jurisdiction.

Tables

Table 2: Marine biotechnology and related firms in Norway[167]

Category		Firm	Product(s) and areas of Research and Development interest	Web address
Developing novel drugs	Drugs for humans	Pronova Biocare AS	Omega 3 based products including Omacor® (generic name: omega-3 acid ethyl esters 90), a pharmaceutical product for the treatment of hypertriglyceridemia.	www.pronovabiocare.com
		Navamedic ASA	Navamedica ASA is a Norwegian speciality pharmaceutical company focussing on the development and production of glucosamine HCI based medicines. Glucosamine is a generic active ingredient which relieves pain and improves function in patients with mild to moderate osteoarthritis in the knee. Navamedica's products have been derived from shrimp shell. The shells are processed into chitin powder from which glucosamine is produced.	www.navamedic.com
		Advanced Biopolymers AS	Commercialisation of polysaccharides (chitosan) useful in drug delivery via mucous membrane of the nose developed by NOBIPOL	
		Biotec Pharmacon ASA	Bioactive compounds & DNA modification of marine based enzymes. It has developed and produces beta-1,3/1,6-glucans for human use and for the animal health sector. The company also produces ultra-pure heat-labile marine enzymes used in molecular biology, gene technology and DNA-based diagnostics (life science).	www.biotec.no
		Hepmarin AS	Anticoagulants based on marine products.	
		Thia Medica AS	Modified fatty acid (TTA) for metabolic disorders	
		Algi Pharma AS	Alginate technologies for cystic fibrosis and wound healing	
	Fish Health	Alpharma AS	Speciality antibiotics and vaccines	www.alpharma.com
		Intervet Norbio AS	Fish health related vaccines and endocrine products. Products include vaccines for prevention of infectious diseases, anti-infectives, anti-parasitics, speciality pharmaceuticals and products for fertility management.	http://aqua.intervet.com/
		Scanvacc	Development and sale of health products for fish farming	www.scanvacc.com
		ACD Oharmaceuticals AS (a subsidiary of Nordly Holding AS)	Research and Development of pharmaceuticals for the aquaculture industry	www.acdpharma.com/ and www.europharmanordic.com/nordly.html

Category	Firm	Product(s) and areas of Research and Development interest	Web address
New types of composite materials, biopolymers and enzymes for industrial use	FMC Biopolymer AS	Biopolymers (alginates and carrageenans) processed from seaweeds and microcrystalline cellulose processed from speciality grades of pulp. The operations of this company also include products marketed under the NovaMatrix™ trademark including biopolymers and biomaterials for use in pharmaceutical, biotechnology and biomedical applications. NovaMatrix´s technology and products are used in the development of novel drug delivery therapies and its polymers are utilized in the formation of biostructures for tissue engineering, wound healing, implants and advanced biotechnology applications. Alginate, chitosan and hyaluronan have proven properties suitable for parenteral administration of challenging drugs and implants.	www.fmcbiopolymer and www.novamatrix.biz/
	Ami Gro As	Splitting fish protein into free amino acid by using enzymatic methods	www.fortuna.no
	Aqua Biotech Technology AS	Enzymes	
	Promar Aqua AS	Algae production for medicinal use.	
	Maritex AS (subsidiary of Tine dairy products)	Research on marine ingredients for use in dietary supplements and fish and animal feed. Includes the subsidiary company Tine Biomarin	
	Napro pharma AS	Develop products from fish oils and omega 3 concentrates for sale to the nutraceutical industry. Bulk marine and vegetable oils for pharmaceutical use.	www.napro-pharma.no
	Natural ASA	Licensing company selling solutions for commercialising of marine products based on fatty acids mainly for use in dietary supplements.	www.natural.no
	Aker BioMarine ASA	Supplier of krill oil and meal to nutraceutical, aquaculture feed and the pharmaceutical markets. Aker Biomarine holds 89.14 of shares in Natural ASA and is interested in potential developments in nutraceuticals (dietary supplements and functional foods) and nutraceutical applications of lipids, product development, intellectual property rights, research and development and product commercialization. This company also has significant interest in fishing including fishing for Patagonian toothfish.	www.akerbiomarine.com
	ProBio Nutraceuticals AS	Production of customised food additives based on fish oils mainly for dietary supplements and nutraceuticals.	www.probio.no
	Firmenich Bjørge Biomarin AS	Natural seafood extracts for production of flavouring materials for the food, beverage and pharmaceutical industries. This company is a subsidiary of the swiss company Firmenich with operations world wide.	www.firmenich.com
	Biohenk AS	Fish waste treatment. Production of chitosan from prawn shells. Sold mainly to the cosmetics industry	http://home.c2i.net/w-200778/bgfabrik.htm
	Primex Biochemicals AS (subsidiary of Primex ehf Iceland)	Chitin derivatives and speciality marine proteins. eg product ReduSan. Also supplies partially hydrolysed marine proteins for various applications in food and feed markets. Primex is the successor of Genis ehf, which acquired the Norwegian company Primex Ingredients ASA in September 2001	http://www.redusan.no/
	Sigtun AS	Bioactive molecular products based on mussels	
	Biopharma AS	Dietary supplements based on marine ingredients (import and sales)	

Category		Firm	Product(s) and areas of Research and Development interest	Web address
		Norferm DA	This company ceased operations on 1 March 2006. However, while in operation it was involved in the development of bioprotein production technology derived from microbes extracted from gas fields in the Norwegian sea.	www.norferm.com
		Biosentrum AS	Contract fermentation	www.biosentrum.no
Cosmetics		Kilda Biolink ASA	Cosmetics based on marine collagen	www.kilda.no/
Safety of aquaculture and fisheries/ providing new techniques for management of marine environments	Genetics	Aqua Gen	Breeding of Atlantic Salmon and rainbow trout based on genetics	www.aquagen.no
		GenoMar	Genetic enhancement of aquatic species and DNA profiling for tracing fish origin. GenoMar has also developed successful DNA vaccine prototypes and diagnostic tests against major salmon virus pathogens.	www.genomar.no
	Feed	Nutreco/ Skrettling (business group of the Dutch company Nutreco Holding N.V)	Feed producer for the aquaculture industry.	www.nutreco.com
		EWOS AS (a subsidiary of the EWOS Group)	Feed producer for the aquaculture industry	www.ewos.com/ and www.ewos.com/no/
		BioMar AS (subsidiary of the Danish company BioMar Holding A/S)	Feed producer. Norwegian operations focus on salmon feed. Has also been involved in commercialisation of alginate based fish feed product for immune stimulation based on research by NOBIPOL.	www.biomar.com and www.biomar.no/
		Polarfeed AS (a subsidiary of Nordly Holding AS)	Development, production, sales and distribution of feed for fish farming	www.polarfeed.no/ and www.europharmanordic.com/nordly.html
	Misc	Biosense Laboratories AS	Biotechnology-based diagnostics for, inter alia, monitoring and detecting environmental contaminants and toxins in the field of food safety including ELISA kits and receptor-based bioassays to detect and quantify concentrations of the major algal toxin groups including Amnesic shellfish poison, diarrhetic shellfish poison, and paralytic shellfish poison.	www.biosense.com/
		Bionor AS	Diagnostic products for human and veterinarian medicine including acquaculture	www.bionor.com
		Promar Aqua AS/ Intravision	Photosynthesis bioreactor for production of micro algae	

Table 3: Companies involved in research and development and marketing of products derived from Arctic Genetic Resources.[168]

Company	Product(s) and areas of Research and Development interest related to Arctic genetic resources	Location, Country	Web address
A/F Protien Inc & A/F Protein Canada Inc.	Develops antifreeze proteins for the control of cold-induced damage in medical, food, and cosmetic products. Anti-freeze proteins are derived from Cold Ocean Teleost Fish including Antarctic notothenioids, Northern Cods, Atlantic and Greenland Cod, Shorthorn Sculpin.	Waltham Massachusetts USA (Administration) and Newfoundland, Canada (Manufacturing and R & D)	www.afprotein.com
Amundsen Omega3 AS	Amundsen Omega3 markets a range of health products containing Omega 3 fatty acids sourced from various Arctic marine sources including Arctic fish and seals. The products are marketed as having a "preventative effect" in relation to cardio vascular diseases and a range of other purported medical benefits.	Based in Bergen, Norway but derives raw materials from the Arctic.	www.amundsenomega3.com/
Arctos Pharmaceuticals Inc[169]	Natural products with value in pharmaceutical, nutraceutical and other biotechnology application. Focus on plants and microbes. Research and development has included work on an organism with both antibacterial and anti-fungal properties. Reliant on assistance provided by local indigenous communities to source appropriate plants based on indigenous traditional knowledge.	Based in Anchorage Alaska, USA. Natural materials sourced from Alaska and Adak Island in the Aleutians	
Aromtech Oy	Focused on research and development of novel nutraceutical, medicinal and cosmetic uses of plant species from Northern Arctic Finland/Lapland. Markets a range of nutraceutical and other products derived from plants such as Arctic birch and peat and wild berries. These products are sold under trademarks including ArcticCare™ (nutricosmetics including berry seed oils, plant derived lipophilic active ingredients and natural fragrances), Omega-7® and Membrasin® food supplements, Ribesin™ ("a food supplement intended for use to control "bad" LDL-cholesterol in blood and to support heart health and the health of the cardiovascular system"), and a range "of special plant derived lipidic substances characterised by exceptionally high content of mono- and polyunsaturated fatty acids." The main focus of on-going research and development is on the following research areas: - Supercritical Fluid Extraction technology - Extraction of functional lipids - Natural aromas & fragrances - Customer orientated projects - Lipid chemistry and nutrition - Lipid analysis - Health effects of functional lipids - New raw materials for health and personal care Collaboration with universities, industry and research institutes is an elemental part of the company's R&D strategy.	Rovanienmi. Lapland, Finland.	www.aromtech.com
Aqua Bounty Technologies	Initially established in 1993 as a division of A/F Protein as a biotechnology company specialising in the commercial development of products exploiting the unique properties of anti-freeze proteins in Arctic and Antarctic fish. Now has much broader operations in aquaculture including transgenic fish.	Canada and USA	www.aquabounty.com

Company	Product(s) and areas of Research and Development interest related to Arctic genetic resources	Location, Country	Web address
Aquapharm-Biodiscovery	This company has a substantial collection of unique marine bacteria and fungi isolated from diverse and extreme marine habitats, including the Arctic and the deep sea, and uses these to develop new biologically active natural products for pharmaceutical, nutraceutical and industrial applications. Aquapharm's patented technology base is the ability to manipulate marine microbial communities to enable the development and production of new molecules of pharmaceutical potential. Its core product areas are: Anti-infectives (new anti-biotic and anti-fungal development), Cartenoid pigments (novel high yield fermentation), new enzymes (bio-transformations), and functional molecules. In addition it also makes its library of marine bacteria and fungi available to third parties for research and development purposes. The company currently has a number of pipeline candidate anti-infective compound leads screened from its library of novel marine bacteria. The core focus is the development of novel antibiotic and antifungal compounds against drug resistant micro-organisms such as MRSA and *Candida albicans*. To date, the company has developed a number of molecules with anti-infective capabilities.	Based in Scotland (United Kingdom)	www.aquapharm.co.uk
Bioneer AS	Bioneer A/S is an independent, research-based service company involved in research and development in the broad fields of biomedicine, biomedical technology and biotechnology. Bioneer has a collection of extremophilic microorganisms from Greenland. This collection serves as a screening source of new enzyme candidates for customers within medicine, biotechnology and food technology sectors.	Hørsholm, Denmark	www.bioneer.dk
Biotec Pharmacon ASA	Biotec Pharmacon develops, manufactures, and markets immune modulating compounds and molecular biology grade enzymes, based on its own research in immunology and marine biotechnology. Biotec Pharmacon is using marine biochemistry and bio-prospecting as its pipeline for novel products for pharmaceutical and life science applications. This company is a partner in the Mabcent Initiative. See Box 5 above.	Norway	www.biotec.no
Bluelagoon	Skin care products based on geothermal seawater and algae derivatives.	Iceland	www.bluelagoon.com
Brimseafood ehf	Fishing and seafood processing company. As part of its main operations it is also involved in 5 scientific projects with MATÍS which is an Icelandic government food research company founded in 2006. Such projects include research on uses of proteins recovered from processing water and value added fish by-products such as protein/gelatine/cytosine.	Iceland	www.brimseafood.is
CRS Biotech	Research and Development of biomaterials (botanicals) and new ingredients for food, nutraceutical supplements, or cosmetic preparations derived from Arctic plants. Core business relates to the chemistry of plants, extracts, distillates, and functional molecules. Currently markets a range of products with nutraceutical, cosmetic and homeopathic applications.	Northern Arctic Finland	www.crsbiotech.fi
Detria Oy	Detria Oy produce and market natural cosmetics and other herbal care products derived from native plants and herbs mainly sourced from Lapland in Northern Finland.	Lapland, Finland	www.detria.fi/web/index.php?id=2

Company	Product(s) and areas of Research and Development interest related to Arctic genetic resources	Location, Country	Web address
FMC Biopolymer	Biopolymers (alginates and carrageenans) processed from seaweeds and microcrystalline cellulose processed from speciality grades of pulp. Alginate used by this company is harvested seaweed from pristine Arctic waters of Norway. The primary brown seaweed utilized by FMC BioPolymer for the extraction of alginates is *Laminaria hyperborea*. This type of seaweed is harvested along the West Coast of Norway, where large "forests" grow naturally in the clean Arctic waters. The plants are harvested in fairly shallow waters, at depths of 2-15 meters. Special trawlers have been developed to harvest this seaweed. FMC BioPolymer is the only alginate producer in the world that harvests *Laminaria hyperborea* mechanically.	Worldwide operations but raw materials sourced from Norway's Arctic waters.	www.fmcbiopolymer.com/
GE Healthcare (formerly Amersham Biosciences)	GE Healthcare markets Shrimp Alkaline Phosphatase and Shrimp Deoxyribonnuclease sourced from the Arctic shrimp *Pandalus borealis*.	Sweden	http://www6.gelifesciences.com/aptrix/upp01077.nsf/content/sweden_homepage
Iceherbs Ltd	Iceherbs Ltd produces health products from Iceland Moss. The main active compounds in Iceland Moss include polysaccharides. Products marketed by this company include Iceland Moss Mixture a cough mixture for relieving coughs and irritation and Iceland Moss Capsules a mineral and dietary supplement. Prokaria ehf (see below) holds a 50% shareholding in this company.	Iceland	www.iceherbs.is
Ice Biotech Inc.	Research and development of cold tolerance technology for plants. Plant anti-freeze proteins.	Canada	www.icebiotech.com
Kelp Products of Florida Inc.	Kelp derived vitamins and supplements for humans, dogs and horses and fertilizer. These products include Ascophyllum Nodosum seaweed from the Norwegian Arctic coastline. Products marketed include the Norwegian kelp "Vegetarian Blend", "Vegetarian Blend & Garlic" Animal Food Supplement, Norwegian Kelp "Granular Dog Food Supplement."	USA but Kelp sourced from Arctic Norway	www.kelpproductsofflorida.com/index.html
Kirkman	Kirkman produces specialty nutritional supplements including a range of Cod liver oil products sourced from Arctic fish including Arctic™ Cod Liver Oil Capsules.	Based in Oregon USA	www.kirkmanlabs.com
Lifeline Cell Technology LLC	Lifeline Cell Technology® (Lifeline) develops, manufactures, and markets human stem cells, media, and reagents for the research marketplace. It is a wholly owned subsidiary of International Stem Cell Corporation, a public stem cell therapeutics company. International Stem Cell Corporation (ISC), Lifeline's parent company, is focused on treating devastating degenerative diseases that clinical research has shown may be treated through the transplantation of human cells. ISC will initially focus on retinal degeneration, diabetes and liver disease. In all three of these fields human cells have been used as treatments in early clinical trials. Once perfected and approved by the USA FDA, the primary barrier to future treatment using these cells is the lack of sufficient cells for the population in need. Lifeline plays a supporting role to ISC by providing cash flow and developing innovative cell manufacturing techniques useful for therapeutic cell production. Lifeline's staff is experienced in manufacturing cells for therapeutic use and will use this experience in the derivation and manufacture of therapeutically useful cells from stem cells. Lifeline Holds an exclusive licence in relation to Arctic Ground Squirel stem cells from Neuronascent Inc. See below and Box 4. These are marketed by Lifeline as Adult Hippocampal Arctic Ground Squirrel Cells (agsNSC™)	Based in Oceanside, California, USA. Lifeline's production and administrative facilities are located in Walkersville, Maryland, USA.	www.lifelinecelltech.com/
Lysi Ltd	Lysi was established in 1938 and its main activities are in the field of marine lipids. It manufacturers and markets a range of consumer and bulk Omega-3 fish oils, Cod liver, shark liver oils, salmon oil, tuna oil, and Squalene.	Iceland	www.lysi.eu

Company	Product(s) and areas of Research and Development interest related to Arctic genetic resources	Location, Country	Web address
Lytix Biopharma	Lytix Biopharma AS is a privately-owned pharmaceutical company focused on anti-microbial and cancer therapeutics. It is a partner in the Mabcent initiative. See Box 5 above.	Norway	www.lytixbiopharma.com
Lumene Group	This company is a major international cosmetics and skin care product manufacturer. Its sells a wide range of products incorporating ingredients such as Arctic berries (including Arctic blackcurrant, Arctic Cloudberry, Arctic cranberry), Arctic Sea Buckthorn, pine tree nettles, birch leaf extract, Arctic peat and pure spring water from Lapland in Northern Finland. Products marketed include "White" Arctic Peat Extract and Lumene Arctic Touch Clarifying Mineral Peeling.		www.lumene.com
Magelin Bioscience Group Inc.	Main field of operation is in microbial extracts for drug discovery, agrochemical, enzyme, and specialty chemical research. Magelin has a collection of over 10,000 marine microbes sourced from the Arctic and Antarctica as well as shallow reefs , marine caves, deep (>1000M) ocean sediments and tropical & temperate Waters. Magelin also has access to one of the largest collections of terrestrial fungi - collected from over 55 countries from around the world. This company maintains its collection of over 60,000 specimens is by far the largest private collection of "culturable" fungi in the world. The companies' web site proudly boasts that this collection is "unencumbered by the 1992 Rio Treaty."	This company is based in Florida, USA.	www.magellanbioscience.com/news.htm
Neuronascent Inc.	Neuronascent is focused on the discovery and development of therapies for Alzheimer's disease, stroke and depression based on the science of neurogenesis that: reduce the loss of neurons; restore and replace damaged neurons; promote the formation of new neurons; and reverse cognitive loss. Neuronascent has developed adult neural stem cells derived from the Arctic ground squirrel. See Box 4 above for further details.	Based in the USA. The Arctic ground squirrel is found in Alaska in the USA and in the Yukon Territory, northern British Columbia and the mainland of the Northwest Territory, Canada.	www.neuronascent.com
Nordic naturals	Omega 3 fish oils for humans and animals including Cod liver oil sourced from Arctic Cod. A range of Omega 3 fish oil products currently marketed. Products include Arctic Pure Ultra Potency Omega-3 fish Oil.	Norway	www.nordicnaturals.com
NorthTaste Ltd	R & D has focused on cold-active (psychrophilic) enzymes and their industrial applications with a particular emphasis on food technology. Have developed and currently markets a range of seafood stocks and flavouring under the NorthTaste trademark. Products marketed include lobster stock, shrimp stock, fish stock, clam stock and seafood stock.	Iceland	www.northice.com
Olivita AS	PUFA Omega 3 based on whale, seal and fish oil.	Norway	www.olivita.com

Company	Product(s) and areas of Research and Development interest related to Arctic genetic resources	Location, Country	Web address
Pharma Mar	PharmaMar is a biopharmaceutical company with headquarters in Madrid (Spain) and laboratories in Cambridge (USA). PharmaMar is fully owned by the Zeltia Group and traded on the Spanish Stock Exchange (ZEL) with a market capitalization of over 1.5 Billion euros. PharmaMar was founded in 1986, and its main business focus is on exploiting the potential of the oceans as a source of novel medicines for improved cancer treatment. PharmaMar has a collection of 50,000 marine organisms obtained from expeditions around the world. 700 new chemical entities have been discovered and 30 new families of compounds have been identified. PharmaMar also has 3 molecules in advanced preclinical development. More than 6,000 cancer patients have already been treated with PharmaMar agents in clinical trials in more than 200 hospitals in Europe, US and Canada. ES-285 is a synthetic molecule being developed by PharmaMar originally found in the mollusc *Mactromeris polynyma* (Arctic Clam). ES-285 has shown preclinical anti-tumour activity in a variety of human tumour types including liver, prostate, kidney and melanoma, and also in models of metastases. Currently it is in Phase I clinical trials in patients with advanced malignant solid tumors.	Spain and USA	www.pharmamar.es/en
Primex ehf	Production of Chitosan and chitin derivatives for use in food, cosmetics, biomedical and industrial applications derived from shrimp shells.	Reykjavik (R &D), & Siglufjordur (Production), Iceland	www.primex.is
Prokaria ehf	Prokaria's main areas of activity are in the discovery, research and development of products and applications from natural organisms. Prokaria's current primary focus is in two fields; a) Environmental genomic applications of thermophilic organisms (bacteria and viruses) from Icelandic geothermal areas and b) applied fish genetics.	Iceland	www.prokaria.com
Pronova Biopharma (previously known as Pronova Biocare)	Pronova BioPharma (previously Pronova Biocare) is a global leader in the research, development and manufacture of marine-originated omega-3 derived pharmaceutical products. The research programs of Pronova BioPharma are aiming at new lipid compounds having more specific biological effects than natural PUFAs, and Pronova BioPharma is focusing on two main therapeutic areas: The cardiovascular/metabolic area and the chronic inflammation area. Pronova BioPharma's emphasis is on a new generation of naturally derived pharmaceuticals based on R&D within the marine area. They actively participate in programs that cover bioprospecting projects that screen marine compounds through professional drug discovery programs and test identified lead compounds through their established network including research organisations and universities. Pronova BioPharma is a partner in the Mabcent Initiative (See Box 5)	Norway and Denmark	http://www.pronova.com/
Probio Group Holdings	Probio Group Holdings is a partner in the Mabcent Initiative See Box 5 above.		

Company	Product(s) and areas of Research and Development interest related to Arctic genetic resources	Location, Country	Web address
SagaMedica ehf	SagaMedica produces and markets high quality natural products made from Icelandic and other Nordic medicinal herbs. Products marketed by this company include Arctic Angelica a syrup said to be effective in increasing energy and for resistance to colds, in reducing stress and as an aphrodisiac. SagaMedica also markets Voxis lozenges for sore throats. Both these products are based on the medicinal herb Angelica archangelica which is believed to be one of the few medicinal herbs originating in the northern hemisphere. The herb is also believed to be one of the few plants which survived the Ice Age in Iceland and Scandinavia.	Iceland	www.sagamedica.com
Seagarden AS	Manufacturer of seafood extracts and powders. Markets Arctic Fish Powder and Arctic Shrimpshell Powder.	Avaldsnes Norway	www.seagarden.no/ssp.html
Skyn Iceland	Produces a range of cosmetics which include ingredients sourced from Icelandic natural sources including, inter alia, Angelica Archangelica, Arctic Cloudberry Seed Oil, and Icelandic kelp. Products marketed include skin moisturisers such as Arctic Face Mist and Nordic Skin Peel.	Iceland	www.skyniceland.com
Source Naturals	Produces a range of vitamins and nutraceuticals derived from both Arctic and Antarctic fish and fish by-products. 11 Arctic or Antarctic derived products are marketed including ArcticPure™ EPA Omega 3 fish oil derived from fish caught in the Arctic Ocean and NKO™ Neptune Krill Oil an Omega 3 Oil derived from Antarctic Krill.	Company based in California, USA. Fish and Krill obtained from the Arctic Ocean and Antarctica.	www.sourcenaturals.com
Scandinanvian Herbal Institute (Swedish Herbal Institute)	The Scandinavian Herbal Institute, part of the Swedish Herbal Institute, is a research and development focused company, originally created as a non-profit research organization with the purpose of collecting information about herbal medicine and promoting scientific research, developing herbal products and spreading knowledge about them. Products marketed by this company include Arctic Root which contains *Rhodiola rosea* allegedly useful in treating stress. Products are distributed in the USA by ProActive BioProducts Incorporated.	Sweden	www.shi.se/index.htm
Unilever	This company is a large food manufacturer that has developed antifreeze proteins derived from artic eel pout for use in making ice cream. See Box 3 above for further details.	Company has world wide operations.	http://www.unilever.com/
Verium Corporation (previously known as Diversa Inc.)	Verium Corporation develops cellulosic biofuels and enzymes. Verium has a broad library of unique enzymes for commercial development sourced from extreme environments including the Arctic, Antarctica, volcanoes, rain forests and deep sea hydrothermal vent microorganisms. Verium is also involved in anti-biotic and other drug research.	Company has operations world wide but has sampled from Alaska (USA) and other Arctic waters.	http://www.verenium.com/index.html
Veterinary Resource Group Inc.	This company markets Wild Arctic Salmon Oil as a source of omega 3 fatty acids. The Arctic Salmon Oil is derived from fish from Alaska	Based in Washington State USA but Arctic Salmon Oil derived from fish from Alaska	www.oceankelp.com/

Company	Product(s) and areas of Research and Development interest related to Arctic genetic resources	Location, Country	Web address
Zymetech ehf.	Zymetech is an Icelandic company that concentrates on research in the field of enzymes and their use in the development and production of pharmaceuticals and cosmetics. Zymetech was established in 1996 as an enzyme research and development company. The company is primarily involved in development, production and marketing of marine enzymes and products derived from such enzymes. Zymetech has developed proprietary patented technology on marine enzymes for pharmaceutical and cosmetic use. Products marketed by this company include PENZIM, a product containing purified enzymes that purportedly brings relief to people suffering from a variety of skin conditions, rheumatic or arthritic diseases, swelling, and muscle pains, among other problems. In addition, PENZIME is a nourishing and healing skin lotion and moisturizer.	Iceland	www.zymetech.com
New England Biolabs	Enzymes isolated from extremophiles including cold loving organisms.	USA	www.ned.com

Table 4: Patents/patent applications based on inventions relating to Arctic Genetic Resources.

Patent / Patent application Number	Title of Invention	Publication Date	Inventor or Assignee (Owner of the Patent Right)	Source	Location of Source (if stated or known)	Application or Uses
AU784783B	Cod uracil-DNA glycosylase, gene coding thereof, recombinant DNA containing said gene or operative parts thereof, a method for preparing said protein and the use of said protein or said operative parts thereof in monitoring or controlling PCR.	15/6/2006	Biotec Phamacon ASA	Atlantic cod (*Gadusmorhua*)	Cold habitats	Useful in research involving polymerase chain reaction (PCR) techniques.
DE202004014947U	Antiwrinkle complex for treating skin treatment, especially in cream base, comprising arctic bog extract as lipid source and grape-seed extract as radical scavenger	16/12/2004	Lifestone GMBH	Arctic bog/artic moorland.		Skin cream.
EP1185661	Bacteriophage RM 378 of a Thermophilic Host Organism	13/3/2002	Prokaria EHF	Marine microbe (*Rhodothermus marinus*)	Iceland	Enzyme for use in DNA research and improved commercial enzyme based products.
FI118117B	Cosmetic product for the treatment of scalp	13/2/2007	Lumene Oy	Juniper including *Junieprus communis* and Lapish Juniper *Juniperus nana*.	Southern and Central Finland and Lapland.	Cosmetic product which can be used for the treatment of scalp including greasy scalp and/or dandruff in the form of shampoo, conditioner, hair tonic, lotion or mask.
JP61277624	Health food made from horn of reindeer	8/12/1986	Osaka Chemical Laboratories; Toshin Tsusho KK.	Reindeer (*Cervidae Artiodactyla*)	Bred in captivity. Found in the Arctic, North Europe and North Asia	Health food having high nutrient or tonic effect. Also used as medicine with, inter alia, analgesic and anti-inflammatory effect.
JP63112522	Nutrient and tonic drug prepared from antler or reindeer	17/5/1988	Osaka Yakuhin Kenkyusho KK	Reindeer (*Cervidae Artiodactyla*)	Bred in captivity. Found in the Arctic, North Europe and North Asia	Nutrient and tonic drug.
RU2128054	Phytotherapeutic agent for an [sic] external use	27/3/1999	Bencharov Jurij Vladmirovich	Lake Baikal water	Lake Biakal, Siberia, Russia	Composition used for treatment of weeping, suppurative wounds, burns and freezings [sic] and can be used as ointment, lotion, cream.
RU2195304	Stomatological species of medicinal herbs (versions)	27/12/2002	Konovalov Valerij Nikolaevich, Konovalova Julijia Vladimirovna	Range of medicinal herbs including Arctic raspberry.		Medicine used for treatment of diseases of teeth and oral cavity [sic].
RU2250780	Strain of bacteria Escherichia Coli for fur game protection from toxicosis associated with colibacillus enterotoxins	27/4/2005	Kozlovskij Ju E, Emel Janenko P A, Plugina I V, Balakirev N A, Tinaeva E A, Molchanova N V	Bowel of Arctic Fox		Improved drug for fur game protection from toxicosis.

Patent / Patent application Number	Title of Invention	Publication Date	Inventor or Assignee (Owner of the Patent Right)	Source	Location of Source (if stated or known)	Application or Uses
US5620732	Method for making ice cream	15/4/1997	The Pilsbury Company	Method involves use of anti-freeze proteins from blood and muscle tissue of Antarctic fish, arctic fish, worms and insects		This patent relates to a method to create ice cream using ant-freeze proteins.
US6133010	Chlamysin B antibacterial protein, a protein gene for and an expression system for same.	5/3/2002	Biotec ASA	Arctic scallop (*Chlamys islandica*)		Anti-bacterial protein with potential as a new anti-biotic drug.
US6492161	Bacteriophage RM 378 of a thermophilic host organism	10/12/2002	Prokaria Ltd	Marine microbe (*Rhodothermus marinus*)	Iceland	Enzyme for use in DNA research.
US6812018	Thermostable cellulase	2/11/2004	Prokaria Ltd	Marine microbe (*Rhodothermus marinus*)	Iceland	Enzyme used in de-inking and refining recycled paper, in consumer products and food industry for extracting and clarifying juice and fruits, brightening colours in clothes.
US6818425	RNA ligase of bacteriophage RM 378	16/11/2004	Prokaria Ltd	Marine microbe (*Rhodothermus marinus*)	Iceland	Enzyme for use in DNA research.
US6958385	Bioactive peptides, uses thereof and process for the production of same.	25/10/2005	Biotec Pharmacon ASA	Cold water fish including Atlantic cod, Norwegian salmon, herring and trout.	Cold water oceans including the North Atlantic Ocean, Bering Sea and Arctic Ocean.	A novel peptide product which is useful for enhancing the growth of warm blooded animals and fish.
US7037703	Cod Uracil-DNA Glycosylase, gene coding thereof, recombinant DNA containing said gene or operative parts thereof, a method for preparing said protein and the use of said protein or said operative parts thereof in monitoring or controlling PCR.	2/5/2006	Biotec Pharmacon ASA	Atlantic cod (*Gadus morhua*)	Cold waters	Enzyme for use in DNA research using Polymerase Chain Reaction (PCR) techniques.
US7052898	Thermostable isomerase and use hereof, in particular for producing tagatose	30/5/2006	Bioneer A/S	Hot spring microbe (*Ther-moanaerobacter mathranii*)	Iceland	Useful in commercial scale production of low calorie sweeteners for use in food products.

Patent / Patent application Number	Title of Invention	Publication Date	Inventor or Assignee (Owner of the Patent Right)	Source	Location of Source (if stated or known)	Application or Uses
US20020141987	Fish serine proteinases and their pharmaceutical and cosmetic use	3/10/2002	Jon Bragi Bjarnason	Atlantic Cod		Used in treating and/or preventing a variety of diseases and disorders such as inflammatory diseases, infectious diseases caused by viruses, bacteria and fungal species. Specific diseases and conditions mentioned include, inter alia, arthritis, acne, eczema, hemorrhoids and infected topical ulcers. The patent also relates to use in cosmetics.
US20030082741	Nucleic acid encoding DNA helicase of bacteriophage RM 378	1/5/2003	Prokaria Ltd	Marine microbe (*Rhodothermus marinus*)	Iceland	Enzyme for use in DNA research and with potential application in commercial settings requiring high temperature enzymes.
US2003068670	Bioactive peptides, uses thereof and process for the production of same	10/4/2003	Raa Jan and Rorstad Gunnar	Cold water fish including Atlantic cod, Norwegian salmon, herring and trout.	Cold water oceans including the North Atlantic Ocean, Bering Sea and Arctic Ocean.	A novel peptide product which is useful for enhancing the growth of warm blooded animals and fish.
US2003019449	Medicinal herbal extract carpediol for treating depression	16/10/2003	Wikman Georg, Panossian, Alexander.	Extracts from plants belonging to the *Crassulaceae* family.	Sweden, Norway, Iceland, Finland and Northern Europe.	Herbal drug for treating mild to moderate forms of depression.
US2003129710	Novel thermostable isomerase and use hereof, in particular for producing tagatose	10/7/2003	Hansen Ole C, Jorgensen Flemming, Stougaard Peter, Bertelsen Hans, Bottcher Karen, Christensen Hans, Jorgen Singel	Hot spring microbe (*Thermoanaerobacter mathranii*)	Iceland	Enzyme suitable for the production of D-tagatose, a useful low-calorie sweetener.
US20060234217	Shrimp alkaline phosphatase	19/10/2006	Nilsen; Inge; Overbo; Kersti; Lanes; Olav	Shrimp (*Pandalus borealis*)		DNA enzyme used in research involving polymerase chain reaction (PCR) techniques.

Patent / Patent application Number	Title of Invention	Publication Date	Inventor or Assignee (Owner of the Patent Right)	Source	Location of Source (if stated or known)	Application or Uses
US20060292226	Fatty emulsion injection of sea oil, method for preparation and the use in manufacturing intravenous injection.	28/12/2006	Liu Wei *et. al*	Several species of seal but predominately harp seal (*phoca groenlandica*). Other seals including the ringed seal (*phoca hispida hispida*), the bearded seal (*erignathus barbatus*), harbour seal (*phoca vitulin concolor*), grey seal (*halichoerus grypus*) and the hooded seal (*cristophora cristata*).	Atlantic and Arctic regions.	Medicinal nutritional application as a means of delivery of lipids via injection when patients unable to eat due to wounds or disease.
US20030082790	RNA ligase of bacteriophage RM 378	1/5/2003	Prokaria Ltd	Marine microbe (*Rhodothermus marinus*)	Iceland	DNA enzyme used in research involving polymerase chain reaction (PCR) techniques.
US20030087392	Nucleic acid encoding DNA polymerase of bacteriophage RM 378.	8/5/2003	Prokaria Ltd	Marine microbe (*Rhodothermus marinus*)	Iceland	Enzyme for use in DNA research and with potential application in commercial settings requiring high temperature enzymes.
US20030092128	Nucleic acid encoding RNA ligase of bacteriophage RM 378	15/5/2003	Prokaria Ltd	Marine microbe (*Rhodothermus marinus*)	Iceland	Enzyme for use in DNA research and with potential application in commercial settings requiring high temperature enzymes.
US20030092134	Nucleic acid encoding 3'-5' exonuclease of bacteriophage RM 378	15/5/2003	Prokaria Ltd	Marine microbe (*Rhodothermus marinus*)	Iceland	Enzyme for use in DNA research and with potential application in commercial settings requiring high temperature enzymes.
WO0238109	Cosmetic compositions containing cloudberry (*Rubus Chamaemorus*) seed oil	16/4/2007	Lumene Oy	Cloudberry (*Rubus Chamaemorus*)	Finland	Use in cosmetics including emulsion creams, lipsticks, hair cosmetics products and products for skin hygiene.
WO2006118463	A combination of seal oil and cold-pressed virgin olive oil	9/11/2006	Olivita AS, Oesterud Bjarne, Elveoll Edel O.	Seal	Norway	Dietary supplement and source of Omega3 fatty acid to counteract the development of coronary heart disease, thrombosis and other inflammatory diseases such as psoriasis and rheumatism.

Patent / Patent application Number	Title of Invention	Publication Date	Inventor or Assignee (Owner of the Patent Right)	Source	Location of Source (if stated or known)	Application or Uses
WO03084559	Vaccinium species compositions with novel beneficial properties	16/10/2003	Arctos Pharmaceuticals Inc.	Berries, leaves, roots, and/or root barks obtained from the Alaskan *Vaccinium* species	Alaska, USA.	Used in treating a wide range of conditions including diabetes, inflammatory disorders, ulcers, viral diseases and disorders, cataracts, glaucoma, cancer, obesity, cardiovascular diseases and for improving vision.

Endnotes

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It was subsequently revised and updated by the author based on a desk top survey of the internet and information sourced from individual company web sites as indicated.
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