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## **Antarctic Bioprospecting: SCAR Survey of Member Countries**



# Antarctic Bioprospecting: SCAR Survey of Member Countries

## Information Paper submitted by SCAR

### Summary

This Information Paper provides further detail in support of WP 16 *Antarctic Bioprospecting: SCAR Survey of Member Countries*.

The paper includes a summary of the responses from the SCAR survey. The findings of a literature search undertaken during early 2020 are included in the Annex.

### SCAR member survey responses

The following provides further detail on the responses received against each of the questions in the survey (which are marked in blue).

1. During the last 10 years (or as appropriate for the data available to you) of activities of your National Antarctic Programme (logistics, or direct funding support, or both), has any research been carried out, or is any research being carried out that is considered to be bioprospecting or natural products research?

*NB: The activity may be a small component of a larger project. In which case, the answer would still be yes.*

15 of 22 (68%) respondent countries responded ‘yes’, to confirm that their national Antarctic programme had carried out or supported research that could be considered ‘bioprospecting’ against the definition provided.

Of these 15 countries 12 are Consultative Parties to the Antarctic Treaty and three are Non-Consultative Parties.

Seven of 22 (32%) respondent countries responded ‘no’.

2. If the answer to Question 1 is Yes, please provide the project title or titles. If these are not available to you, please provide a contact name and e-mail address for a source (or sources) who would be able to supply the project titles?

The 15 countries that confirmed that their national Antarctic programme had carried out or is carrying out research that could be considered ‘bioprospecting’, provided lists of several projects or programmes that they felt met the definition provided.

These were either very specific and targeted projects (e.g. single genus or species research projects) or broad multi-species / multi-ecosystems surveys and programmes.

A total of 78 projects or programmes were listed in the responses provided. These could be divided into the following broad categories as being the primary focus of the research:

• Marine organisms	10
• Terrestrial organisms	28
• Freshwater organisms	5
• Sea ice organisms	3
• Land ice organisms	2
• Mixed ecosystems studies	12
• Unidentifiable from the information provided	<u>18</u>
	78

Although not always identified in the responses, the majority of these appeared to be government funded projects or programmes. One respondent country specifically identified one project as being privately funded.

3. During the last 10 years (or as appropriate for the data available to you) of activities of your National Antarctic Programme (logistics, or direct funding support, or both), has any research been carried out, or is any research being carried out that could contribute to, or later be used for bioprospecting or natural products research? *e.g. gene sequencing, collections of genetic material, biochemical analyses or extractions, isolation of microorganisms or taxonomic research.*

16 of 22 (73%) respondent countries responded 'yes', to confirm that their national Antarctic programme had carried out or supported research that could later be used for bioprospecting or natural products research.

Of these 16 countries 10 are Consultative Parties to the Antarctic Treaty and six are Non-Consultative Parties.

Three respondents qualified their positive response by noting that whilst some of their government funded projects *could* result in commercialisation at a later stage, this was not the goal or motivation for the research at the time funding was awarded.

Six of 22 (27%) respondent countries responded 'no'.

4. If the answer to Question 3 is Yes, please provide the project title or titles. If these are not available to you, please provide a contact name and e-mail address for a source (or sources) who would be able to supply the project titles.

In addition to the projects and programmes recorded in response to Question 2, respondents referred to 'numerous' biological research projects carried out in the Antarctic Treaty area that had the *potential* to contribute to bioprospecting or natural products research.

These projects covered marine, sea ice, terrestrial, freshwater and glaciological (including ice shelf) environments. The projects listed covered an array of scientific investigations including biological material collections, genetic and genomic analyses, biochemical analyses, physiological studies and ecological studies.

Studies covered an array of organisms including viruses, bacteria, yeasts, micro- and macro-algae, protists and terrestrial invertebrates. Molecular ecology and genetic studies on higher organisms (sea birds, fish, pinnipeds and cetaceans) were also recorded.

Many biological studies were focussed on adaptations of Antarctic organisms and their potential responses to changing environmental conditions.

5. During the last 10 years (or as appropriate given the data available to you), has your National Antarctic Programme had, or does it have any associations with other research or commercial entities that are directly associated with bioprospecting or natural products research or commercialisation?

Four of 22 respondent countries responded 'yes' to confirm that their national Antarctic programme had cooperated or was actively cooperating with research or commercial entities that are directly associated with bioprospecting or natural products research or commercialisation.

Of these four countries all are Consultative Parties to the Antarctic Treaty.

18 of 22 respondent countries responded 'no'.

6. During the last 10 years (or as appropriate given the data available to you), has your National Antarctic Programme or researchers or other organisations associated with your National Antarctic Programme applied for any patents that could be classified, under any definition, as the outcome of bioprospecting or natural products research activities?

Four of 22 respondent countries responded 'yes' to confirm that at least one patent application had been applied for as a result of research undertaken or supported by their national Antarctic programme.

Of these four countries all are Consultative Parties to the Antarctic Treaty.

18 of 22 respondent countries responded 'no'.

7. If the answer to Question 6 is Yes, please provide: the title of the patent(s); the date of application; the country or countries in which the patent was applied for, and whether or not the patent has been granted. If this information is not available to you, please provide a contact name and e-mail address for a source (or sources) who would be able to supply the information.

The details that were provided in response to this question are shown in the table below.

Patent title	Date of application	Countries in which patent applied for	Patent granted?
Antibiotic compounds (Product patent)	2010 and 2012	India, Mexico	Yes
Microparticle formulation for pulmonary drug delivery of anti-infective molecule for treatment of infectious diseases	2011 and 2013	India, Mexico, USA	Yes (in all three countries)
Antagonist activity of the fungus <i>Metschnikowia australis</i> extract on P2X7 receptors and its use in the treatment of P2X7 receptor-related diseases (anticancer)	2014	Brazil	Yes
Mass producing method of anti-freezing protein derived from arctic yeast	2013	USA	Yes
Antifreezing agent of exopolysaccharide from <i>Pseudoalteromonas sp.</i> Strain CY01	2018	Republic of Korea	Yes
Establishment of a method of protoplast isolation for the Antarctic plant <i>Colobanthus quitensis</i>	2018	Republic of Korea	Yes
Genetically modified bacteria producing two DNA repair enzymes and method for the evaluation of DNA repair activity.	2018	USA, Uruguay, Brazil	In progress

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## Annex

### Literature search

The peer reviewed academic literature is replete with papers of relevance to research on psychrophilic (cold-adapted) extremophiles as well as on their actual or potential commercial use.

Searches on Google Scholar<sup>1</sup> for the period since 2010 (the period covered by this survey) produced the following results, though it is emphasised that not all of the searchable items relate to the commercial application of biologically-derived products:

Search term	Number of returns
Antarctic gene*	24,600
Antarctic genom*	2,840
Antarctic biotech*	15,800
Antarctic biochem*	16,600
Antarctic extremophil*	11,700
Antarctic biopros*	242

Extremophiles are organisms that have evolved and developed a wide variety of strategies to live and reproduce under harsh conditions, such as exceptionally high or low values of temperature, pressure, oxygen, carbon dioxide, acidity, nutrient content, water content, salt content, etc. Extremophiles are found in a variety of natural ‘extreme’ environments (at least to humans) such as hyper-arid deserts, oceanic deeps, salt lakes, volcanoes and the polar regions (Jorquera et al, 2019).

Research into how life prevails in such environments has generated important discoveries and new levels of understanding about biological adaptation and the evolution of life on Earth. Such research has also provided a boon for biotechnology and related commercial industries (Cavicchioli et al, 2011).

Recent advances in ‘omics technologies’ (i.e. techniques that are used to evaluate the genomics, proteomics, and metabolomics of organisms) has resulted in a rapid expansion in the investigation of extremophile properties and their bioactive compounds, revealing their relevance and application in multiple disciplines including bioprospecting and biotechnology, medicine, bioenergy and biofuels, bioinformatics, biomaterials, biosafety and biosecurity, aquatic biotechnology, agriculture, environmental science, nano-biotechnology, industrial process and more (Jorquera et al 2019).

In the academic literature the life and applications of extremophiles (including, but not limited to psychrophiles – cold-adapted organisms) has been the focus of special issues in the journals ‘*Environmental Microbiology*’ (Volume 13, Issue 8, 2011) and ‘*Environmental Microbiology Reports*’ (Volume 16, Issue 6, 2014) and a thematic issue in ‘*Microbial Biotechnology*’ (Volume 4, Issue 4, 2011).

The Journal ‘*Extremophiles*’ has published 158 articles on the biochemistry, biotechnology or ecology of Antarctic microorganisms since 2010, though (again) not all of these relate to the commercial application of products.

A sampling of the literature reveals a wide range of genetic, biochemical and biotechnological studies on Antarctic freshwater, terrestrial, snow and ice, and marine organisms. These include, for example:

- archaea (Campanaro et al, 2010);
- viruses (Luhtanen et al, 2018);
- yeasts (Ferreira et al, 2019; Watanabe et al, 2014; Zisis et al, 2015; Vlaev et al, 2013);
- soil bacteria (Jiang et al, 2017; Bhave et al, 2013);

<sup>1</sup> Undertaken in December 2019

- snow bacteria (Baricz et al, 2018);
- freshwater bacteria (Das et al, 2019);
- marine bacteria (Park and Kim, 2018; Eronen-Rasimus et al, 2017; Kube et al, 2013);
- fungi (Duran et al, 2019; Martorell et al, 2019; Godinho et al, 2015; Melo et al, 2014);
- lichen (Bhattarai et al, 2013; Paudel et al, 2011);
- terrestrial invertebrates (Carapelli et al, 2014);
- marine algae (Schulze et al, 2019; Gwak et al, 2010), and
- higher plants (Koc et al, 2018).

Polar organisms have been referred to as being “enormous sources of bioactivity compounds” (Liu et al, 2013). Compounds derived from cold-adapted organisms have a wide range of commercial applications. Their biomolecules, mainly proteins and enzymes characterized by a high catalytic activity and pronounced heat-lability, have already found useful applications in various domains such as molecular biology, medical research, food or feed technologies, as well as detergents and cosmetics (Margesin and Feller, 2010).

A literature search revealed many examples since 2010 of studies dedicated to the potential and realised commercial application of products derived from Antarctic organisms, of which the following are examples.

#### *Medical applications*

- Over 200 patents have been filed related to the biotechnological potential of Antarctic micro-organisms (Yarzabal, 2016) with antimicrobial compounds being a particular focus (Lo Giudice and Fani, 2016; Tedesco et al, 2016; Dimitrova et al, 2013).
- Pigments obtained from bacteria isolated from freshwater lakes in the Schirmacher Oasis have been shown to display useful antibacterial properties (Mojib et al, 2010).
- A compound extracted from the Antarctic cyanobacterium *Nostoc* has demonstrated potent antibacterial activity including against *Staphylococcus aureus*, *Salmonella typhi* and *Escherichia coli* and is regarded as an enormous resource of therapeutic biomolecules for future drug development (Liu et al, 2013).
- Substances derived from Antarctic lichens have been shown to have a number of medical applications (Kumar et al, 2014). Ramalin, a secondary metabolite from the Antarctic lichen *Ramalina terebrata* has been shown to significantly inhibit the migration and invasion of colorectal cancer cells (Suh et al, 2017), as well as showing potential antioxidant and anti-inflammatory properties (Paudel et al, 2011).

#### *Food technology*

- The yeast *Candida antarctica* produces two lipases, A and B (lipases being enzymes that break down fats). Lipase B is involved in a very large number of organosynthesis applications related to food/feed processing, pharmaceuticals, or cosmetics. In a 2005 survey of patents related to Antarctica (Lohan and Johnston, 2005), it was shown that lipases from *C. antarctica* dominate the number of process- or product-based patents (Feller, 2013).
- Cold-active enzymes such as antifreeze proteins (AFPs) and ice-nucleating proteins (INPs), from Arctic and Antarctic bacteria have been used in food processing to improve milk fermentation, to store frozen yogurt, and to improve ice-cream production (Cid et al., 2016; Feller, 2013).
- Xylanase (a key ingredient of industrial bread dough conditioners) from an Antarctic bacterium has been demonstrated to be very effective in improving dough properties and final bread quality and is a psychrophilic enzyme produced commercially in significant volume (Feller, 2013).

#### *Agriculture*

- Recent research has demonstrated that plant growth-promoting rhizobacteria and endosymbiotic fungi isolated from an Antarctic plant can effectively reduce the physiological impact of saline stress in a salt-susceptible crops. Plants inoculated with microorganisms collected from Antarctica increased the fitness related traits in several crops (Acuña-Rodríguez et al, 2019).

*Nutraceuticals*

- Antarctic marine bacterial isolates show significant potential as cost-effective alternative sources of long-chain polyunsaturated fatty acids that belong to the omega-3 group - essential fatty acids in the human diet normally provided by fish and fish-derived products (Bianchi et al, 2014).

*Domestic products*

- Psychrophilic subtilisins (protein-digesting enzymes) isolated from an Antarctic *Bacillus* species have been used to develop cold-active subtilisins in washing detergents used in low temperature washes (Feller, 2013).

*Remediation of pollutants*

- Antarctic bacteria have been shown to have heavy metal resistance and hydrocarbon degradation capabilities which are useful for bioremediation in cold environments (Orellana et al, 2018). Antarctic bacteria capable of degrading crude oil at low temperatures, even below the freezing point, have also been reported (Bowman and Deming, 2014).
- The Antarctic yeast *Pseudozyma antarctica* produces enzymes with useful application in the degradation of biodegradable plastics (Watanabe et al, 2014).

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There are many more examples in the literature that could be cited, with Antarctic psychrophilic organisms demonstrating huge potential with regard to an array of commercial applications. Authors have commented that the field of application of these organisms will be enlarged and open up many more new opportunities in biotechnology because of their unique characteristics and easy availability (Banerjee et al, 2016; Liu et al, 2013).



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