

3.1 Marine Biodiscovery/ Biotechnology Research Programme

3.1.1 Introduction

Biotechnology is widely expected to be one of the major technologies of the 21st century. It has already had a major impact on healthcare, and is rapidly realising its potential to dramatically affect agriculture and environmental management. Biotechnology is also expected to be a significant force in the marine sector. Biotechnology is based essentially on using nature's own technology for the production of goods and services. The seas are a major source of organisms with novel biological materials and unique metabolic mechanisms. These can be a source of new mechanisms and materials for further biotechnological applications.

In addition to the opportunity to identify new bioactive substances and processes, biotechnology may also have direct impacts on current marine industries by, for example, introducing breeding technologies and veterinary therapeutics to fish farming, or providing technologies to upgrade marine materials or treat problematic waste materials. It will also continue to be a major driver in the development of functional foods and nutraceuticals.

Furthermore, broader advances in interdisciplinary science—such as information technology, nanotechnology and bio-complexity—provide significant new dimensions for the development of marine biotechnology. There is a strategic opportunity for Ireland in the intensifying convergence of science and engineering disciplines.

3.1.2 Current Status

In considering Ireland's strategic position to undertake a marine biotechnology programme, our assets include a relatively strong (and rapidly growing) research base and a high output of trained graduates. There is also a small cohort of marine and biotech companies that could exploit the outcomes of a marine biotechnology programme.

> Ireland has biotech expertise within several S&T institutions that can support a national effort in marine biotechnology. National capability in biotechnology research will increase because of current national investment in expertise (e.g. through SFI) and research facilities (through PRTLII—the HEA Programme for Research in Third-Level Institutions). This national capability can be applied in the marine sector if there is an appropriate programme to highlight the opportunities, provide the specific

supports required, and manage the inter-disciplinary activities that will be needed.

- > In addition to the availability of suitable R&D support for a national effort in marine biotech, there is also significant support for the commercialisation of the output of such research. Funding and support for the transfer of research outputs, and for the creation and growth of viable new marine biotech companies, are available from Enterprise Ireland and other agencies.

Within Ireland, no single institution has the capabilities to undertake all elements of a marine biotech programme. In addition to the Marine Institute, there is a range of institutions that clearly have roles to play in such an initiative. The Institute has been proactive in the recent past in identifying the opportunities for Ireland to develop a marine biotechnology programme. This has primarily concentrated on Marine Biodiscovery—the investigation of marine organisms for their potential to provide novel biomaterials for use in the drugs, biopharma and materials industries.

A programme is currently being prepared, for funding approval, which will leverage significant investments that have already been made in marine research infrastructure—Marine Institute facilities and vessels—and, through PRTL and SFI, in Ireland’s biotechnology research infrastructure. This covers a linked chain of activities (see Figure 3.3).

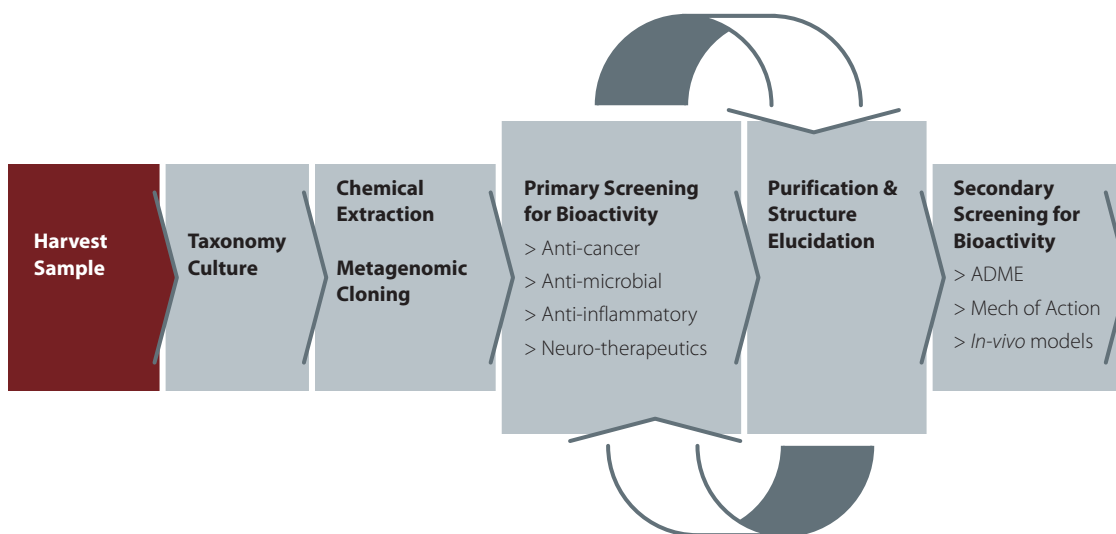


Figure 3.3 Linked Chain of Activities to Create R&D Platform to Underpin Development Opportunities in Biopharma and Medical Device Industries

3.1.3 The Rationale for Marine Biotechnologies

Eighty percent of living organisms are found only in aquatic ecosystems, yet little is known about their biochemical characteristics. The marine biotechnology sector is, therefore, in the early stages of its development, with growing levels of activity in the USA, Japan, the UK and other countries.

A recent report commissioned by the UK’s Foresight Marine Panel states that “with a global market valued at \$2.4 billion in 2002, and a predicted growth rate exceeding 10% per annum over the next three years, there is no doubting that marine biotechnology represents one of the most exciting emerging technology sectors”¹⁹. An earlier report described the US marine biotechnology industry and the emerging market for marine biotechnology products and services, and predicted that the global

¹⁹ Biobridge Ltd. (2005). Study into the Prospects for Marine Biotechnology Development in the United Kingdom. (http://www.dti.gov.uk/marine_biotechnology_report.html)

marine biotechnology market would surpass \$3.2 billion by 2007, with the non-U.S. segment comprising the bulk of the market.²⁰

Marine biotechnology is unlike other areas of biotechnology, in that it is defined in terms of its source material, rather than the market it serves. It is anticipated that it will eventually contribute to nearly every industry sector, from healthcare to bio-remediation and cosmetics to nutraceuticals. The fact that marine biotechnology is at an early stage of development means that much more of the potential global market is open for development by Ireland than is the case in other sectors. Given that Ireland has built up significant R&D capabilities in health-related biotechnology, and that there is a growing pharmaceutical and biopharma industry sector, marine biotechnology, and particularly biodiscovery, could have significant potential to develop the marine knowledge economy. Other areas for which there is strategic rationale for a focused RTDI effort are Genomics and Functional Foods.²¹

1 Biodiscovery—Bioactive Materials

There is an international resurgence of interest in natural products as a source of novel bioactive substances for the development of novel drugs and therapies.

Ireland has developed much of the marine research and biotechnology and medical research infrastructure and capability necessary to establish an integrated chain of marine biodiscovery activities. In addition to creating a significant 'value-added' aspect to a wide range of research investments, the opportunities that will arise from exploring Ireland's marine resources from an entirely different perspective include:

Drugs

- > Novel business opportunities for Ireland in the areas of drugs, industrial enzymes and biological probes as discoveries are made and optimised;
- > Provision of chemical and protein drugs for disease (targets identified as part of the State's research programmes in biotechnology); and

Biomaterials for the Medical Device and Diagnostics Sectors

- > The creation of a strong synergy with the medical device and diagnostics sectors to test compounds isolated as part of the Marine Biodiscovery programme.

2 Functional Foods/Nutraceuticals

Other potential areas in which biotechnology could play a role include foods and feeds. These include the so-called functional foods, which have a health benefit beyond their nutritional content. The Marine Institute, working in association with other stakeholders, is defining a marine functional foods research programme. The vision, objectives and key research outputs for a marine functional foods programme are presented in Section 3.3.

²⁰ McWilliams (2003). Biomaterials from Marine Sources. (<http://www.bccresearch.com/biotech/C184R.html>)

²¹ CIRCA (2004). A Comparative Study of Marine Biotech RTD and Industrial Development Strategies 2004.

3.1.4 2020 Vision

2020 VISION

By 2020, Ireland will have a leading capability in the utilisation of marine organisms and materials for the production of drugs, advanced biomaterials and nutraceuticals. This will feature:

- > A strong collaboration with the growing biopharma sector in Ireland;
- > A synergy with the medical device and diagnostics sector; and
- > Emergence of a number of successful companies selling highly advanced products and services.

Marine materials will form the basis of high added-value products in the new and emerging industry sectors of functional foods, health treatment, diagnostics and informatics and in environmental monitoring. The nanotechnology sector will use marine materials as fundamental components in novel nano-bio health, environment and energy applications. There will be a strong inter-agency partnership and synergy with other RTDI performers across these areas.

3.1.5 2013 Objectives

The following objectives have been identified as critical milestones to be achieved by 2013:

2013 OBJECTIVES

- 1 Create a strong, interdisciplinary capability in the utilisation of marine biodiversity, using novel high-throughput techniques, for the development of drugs, therapies and biomaterials.
- 2 Develop core research capabilities and teams in taxonomy, natural products chemistry, chemogenomics and bioinformatics.
- 3 Develop capabilities for the isolation and identification of novel chemical compounds or proteins for use by the medical device industry (e.g. adhesives and biofilms).
- 4 Create science-based capability to support development of opportunities in functional foods based on marine raw materials, and develop strong synergies with research and development programmes in the seafood, food and health sectors.
- 5 Develop opportunities for participation in internationally funded programmes.

3.1.6 RTDI Requirements/Key Outputs

The identified RTDI requirements and key outputs for delivering on the 2013 Objectives of the research programme are presented below.

Table 3.2 Research Requirements & Key Outputs for Marine Biotechnology/ Biodiscovery to 2013

Objectives 2013	RTDI Requirements	Key Outputs
<p>1 Create a strong, interdisciplinary capability in the utilisation of marine biodiversity, using novel high-throughput techniques, for the development of drugs, therapies and biomaterials.</p>	<ul style="list-style-type: none"> > Identification and analysis of biodiversity 'hotspots' in the Irish marine environment > Implementation of a sampling, processing and storage procedure for marine biomaterials > Enhancement of marine taxonomic capabilities > Implementation of high-throughput systems for metagenomics > Establishment of a chain of primary screening activities to identify novel bioactivities for compounds developed > Development of current core capabilities and collaborations to purify and elucidate the structure of novel compounds with bioactivity > Enhancement of core capabilities in synthetic chemistry to design new drugs based on novel compounds with bioactivity > Establishment of a chain of secondary screening tests to examine the safety and toxicology of the novel compounds with bioactivity 	<ul style="list-style-type: none"> > Novel chemical compounds or proteins that will serve as starting structures to design and develop new drugs > New synthetic methodologies for pharmaceutical production > New enzymes identified and isolated for use in chemical synthesis of pharmaceutical products > New enzymes and new methods to improve the manufacturing of drugs
<p>2 Develop core research capabilities and teams in taxonomy, natural products chemistry, chemogenomics and bioinformatics.</p>	<ul style="list-style-type: none"> > Co-ordinated inter-agency and multi-disciplinary projects, funded over extended time-periods, which will allow for the building of essential scientific capabilities to explore, map and exploit Ireland's marine bio-resources 	<ul style="list-style-type: none"> > Unique marine database linking marine, biological and chemical information within a single system > Closer collaboration between biologists and chemists > New MSc and PhD degrees > Alliances and collaborations with international groups
<p>3 Develop capabilities for the isolation and identification of novel chemical compounds or proteins for use by the medical device industry (e.g. adhesives and biofilms).</p>	<ul style="list-style-type: none"> > Screening programme to identify other resources for use by medical device and diagnostics industry > Development of expertise in niche areas relevant to compounds that could be used by medical device industry 	<ul style="list-style-type: none"> > Novel chemical compounds or proteins that may have uses in other sectors, e.g. medical devices, diagnostics, food additives, industrial uses > Increased R&D in medical device industry based on new materials > An indigenous diagnostics industry > Enhanced glycobiology research

continued

Table 3.2 Research Requirements & Key Outputs for Marine Biotechnology/ Biodiscovery to 2013

Objectives 2013	RTDI Requirements	Key Outputs
4 Create science-based capability to support development of opportunities in functional foods based on marine raw materials, and develop strong synergies with research and development programmes in the seafood, food and health sectors.	> The Marine Institute, working in association with other stakeholders, is defining a marine functional foods research programme	> Key research outputs for a marine functional foods programme are presented in Section 3.3
5 Develop opportunities for participation in internationally funded programmes.	> Not applicable	

3.1.7 RTDI Capacity/Capabilities

Current Research Capacity

Third-level Sector

In the absence, to date, of targeted marine biotechnology research programmes and funding opportunities, research expertise has developed in an *ad hoc* and opportunistic manner. However, a number of the larger marine research groups have attracted funding for marine biotechnology-related projects, e.g. in UCC and NUIG. A small number of research groups with applied marine biotechnology focus have also emerged recently, e.g. DIT (Marine Biotechnology Research Group) and Letterkenny IT (Centre for Applied Marine Biotechnology). Other groups with research interests beyond purely marine topics also participate in marine biotechnology research, e.g. National Diagnostics Centre, NUIG.

Ten research groups in six third-level institutes are currently actively involved in marine biodiscovery/biotechnology research. Together, these groups comprise approximately 52 researchers with research interests covering a wide range of topics (Table 3.3).

Table 3.3 Overview of Current Marine Biodiscovery/Biotechnology Research in the Third-level Sector

Institutes	No. Research Groups	No. Researchers*	Research Focus
NUIG UCC UCD LYIT DIT WIT	7 Large Groups 2 Medium Groups 1 Small Group	52	<ul style="list-style-type: none"> > Molecular biology > Functional genomics > Differential gene expression technology > Molecular glycobiochemistry > Biodiscovery > Molecular phylogenetics & population genetics of sponges > Taxonomy, classification and evolution > Extraction of novel compounds from marine algae > Enzyme screening of macroalgae > Nutritional value of seaweeds > Analytical biochemistry > Biosampling and bioanalysis > Novel uses for marine extracts > Endocrinology > Proteomics > Fluorescence methods for detection of algal species > Stress biomarkers in fish > Tissue culture > Applied marine biotechnology (e.g. molecular methods for detection of shellfish larvae - DNA biosensors, molecular beacons) > Multiplex diagnostics > Use of seaweed for bioremediation of metals

Large: >10 researchers; Medium: 5–10 researchers; Small: <5 researchers

* In some cases, research groups may focus on more than one marine-related theme and the total number of researchers in these groups is greater than indicated here. The total number of researchers in the groups identified is approximately 100.

In addition to these teams, a large number of research groups throughout the third-level sector have relevant expertise/technologies in the broader field of marine research and/or biotechnology (including environmental biotechnology). A recently completed study of marine biotechnology RTD opportunities in Ireland provides a broad overview of marine biotechnology and general biotechnology research and expertise in Irish Universities and Institutes of Technology²².

Marine Biodiscovery

The Marine Institute recently conducted an exercise to identify third-level and state sector research expertise in support of a Marine Biodiscovery Programme. Much of the expertise identified in the third-level sector comes from large research groups with no previous links to marine related research (Table 3.4).

²² CIRCA (2004). A Comparative Study of Marine Biotech RTD and Industrial Development Strategies.

Table 3.4 Third-level Research Expertise in Support of a Marine Biodiscovery Programme

Institute	Research Focus	Institute	Research Focus
NUI Galway	<ul style="list-style-type: none"> > Taxonomy of marine macro and micro-organisms > Glycobiology > Bioinformatics > Bio-medical devices 	DCU	<ul style="list-style-type: none"> > Primary and secondary screening of compounds > Diagnostics > Fluorescent compounds > Bioinformatics
UCC	<ul style="list-style-type: none"> > Metagenomics > High-throughput technology > Primary and secondary screening of compounds > Synthetic chemistry (structure identification and elucidation) > Synthesis of bioactive compounds 	RCSI	<ul style="list-style-type: none"> > Mass spectroscopy based sequencing > Bioinformatics > Proteomics > Genomics
TCD	<ul style="list-style-type: none"> > Primary screening for bioactivity (Cellomics platform) > Secondary screening 	NUI Maynooth	<ul style="list-style-type: none"> > Bioinformatics > Metagenomics > Systematics
UCD	<ul style="list-style-type: none"> > Synthetic chemistry (structure identification and elucidation) > Sequencing technology > Bioinformatics 	Athlone IT	<ul style="list-style-type: none"> > Biopolymers > Drug discovery

State Sector

The Marine Institute research vessel has sophisticated mapping technology to identify biodiversity hotspots. Dedicated lab facilities for sampling, processing and storage of marine material are being developed at the Marine Institute's new facility in Galway. The Marine Institute has close relationships with the National Cancer Institute (US) and the Australian Institute of Marine Science to help develop the biodiscovery programme.

Teagasc are developing research strength in nutraceuticals and could develop a screening programme as part of the biodiscovery programme.

The Biotechnology Directorate team of Enterprise Ireland (EI Bio) forms a crucial link in the commercialisation chain for biotechnology research; connecting the researchers, entrepreneurs and industry. The team works to commercialise the outputs of publicly funded research for Ireland's food, health and life sciences sectors. EI Bio has five strategic focus areas (Pharma & Healthcare, Food & Agriculture, EU Programmes, Publicly Funded Research, and Bioincubation) each with a multi-disciplinary team skilled in the three core competencies of project/strategic management, relevant technologies, and research commercialisation. This expertise can contribute to achieving the 2013 Objectives in relation to marine biotechnology.

Industry

The extent of R&I capacity within the Irish biotechnology industry is difficult to quantify. Capacity within the marine biotech industry, which is a subset of the larger biotech industry, is even more difficult to quantify. A 2002 report on the Irish biotech sector reported that the 59 biotech companies in Ireland (41 indigenous and 18 multinationals) had approximately 400 R&D staff (out of a total of 2,800)²³.

Identification of Research Skills/Competencies to Meet Future RTDI Requirements

A summary, based on the identified future RTDI requirements, of the competencies required to meet the 2013 Objectives is presented in Table 3.5. Also included in Table 3.5 is an assessment of whether there are current strengths (S), areas that require strengthening (R), or gap areas (G), in relation to the identified requirements, within the existing research community.

Table 3.5 Competencies Required to Meet Future Research & Innovation Requirements Related to Marine Biodiscovery/Biotechnology

Objectives 2013	Competencies Required	Assessment
1 Create a strong interdisciplinary capability in the utilisation of marine biodiversity, using novel high-throughput techniques, for the development of drugs, therapies and biomaterials.	<ul style="list-style-type: none"> > Sample collection and identification > Marine taxonomy > Extract production > Biological testing (primary assay) > Chemistry (Natural products) > Chemistry (Synthetic/Development) > Biological testing (secondary assay) > <i>In-vivo</i> assessment > Metagenomics > Chemogenomics > Proteomics > Gene-chip technology 	<ul style="list-style-type: none"> S R G R G S G G R G R R
2 Develop core research capabilities and teams in taxonomy, natural products chemistry, chemogenomics and bioinformatics.	<ul style="list-style-type: none"> > Marine taxonomy > Chemistry (Natural products) > Chemogenomics > Bioinformatics 	<ul style="list-style-type: none"> R G G R
3 Develop capabilities for the isolation and identification of novel chemical compounds or proteins for use by the medical device industry (e.g. adhesives and biofilms).	<ul style="list-style-type: none"> > Chemistry (Natural products) > Extract production > Biomedical engineering > Advanced materials 	<ul style="list-style-type: none"> G G S R
4 Create science-based capability for development of opportunities in functional foods, based on marine raw materials, and develop strong synergies with research and development programmes in the seafood, food and health sectors.	Not applicable	
5 Develop opportunities for participation in internationally funded programmes.	Not applicable	

* S – Current Strength; R – Requires Strengthening; G – Gap Area.

²³ Circa Group (2002). Mapping Study of the All-Ireland Private Biotechnology Sector. Report submitted to InterTrade Ireland.

Although there is some current strength in the expertise required to implement a marine biodiscovery programme (Objectives 1-3), there are also many gaps (e.g. chemogenomics, natural products chemistry and extract production). Other areas of expertise require further strengthening and broadening (e.g. metagenomics, proteomics and bioinformatics).

In addition, current marine biotechnology research expertise is fragmented and un-focused. However, as with many of the programme areas in this Strategy, marine biotechnology development can draw on a large pool of research expertise in the wider biotechnology area in both the third-level and industry sectors. Focusing this expertise on marine biotechnology related research would assist greatly in meeting the 2013 Objectives.

Current Strengths	Require Strengthening	Gaps
<ul style="list-style-type: none"> > Sample collection and identification > Chemistry (Synthetic/ Development) > Biomedical engineering 	<ul style="list-style-type: none"> > Marine taxonomy > Biological testing (primary assay) > Metagenomics > Proteomics > Gene-chip technology > Bioinformatics > Advanced materials 	<ul style="list-style-type: none"> > Extract production > Chemistry (Natural products) > <i>In vivo</i> assessment > Chemogenomics > Biological testing (secondary assay)

Figure 3.4 Research Competencies Required to Meet 2013 Objectives for Marine Biodiscovery/Biotechnology

3.1.8 Prerequisites for Achieving Objectives

The key prerequisite for delivering the objectives in the marine biotechnology field is the creation and funding of an initial co-ordinated core programme that will:

- > Establish new collaborative working relationships between relevant institutions and disciplines;
- > Develop new awareness and approaches to the mapping, sampling and utilisation of Ireland's marine biodiversity; and
- > Initiate new value-added collaborative chains with indigenous industry and multinationals.

Related requirements include:

- > Recruitment into Ireland of high-level experts in a number of areas, including taxonomy, natural products chemistry and chemogenomics;
- > Enhancement of sampling infrastructure, e.g. ROV and/or manned submersible, (see Infrastructure Programme), and chemical extraction, processing and repository capability; and
- > Implementation of efficient processes for the treatment of Intellectual Property (IP), e.g. by applying the ICSTI Code of Practice²⁴.

The implementation of a Biodiscovery Programme also requires the further development of the marine research infrastructure that gives rise to the possibility of such a programme in the first place. In particular, adding value to resources identified through mapping Ireland's marine biodiversity necessitates that the tools for this mapping continue to be enhanced, notably the Seabed Survey and infrastructure items such as ROVs.

²⁴ ICSTI (2004). National Code of Practice for Managing Intellectual Property from Publicly Funded Research. Irish Council for Science, Technology and Innovation.