



MARINE BIOTECHNOLOGY IN THE BIO-ECONOMY

OECD BNCT

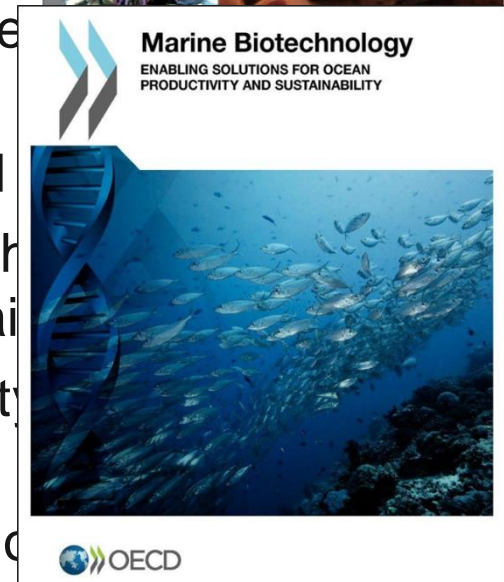
Gent 18 January 2016

Kathleen D'Hondt



Context

- Opportunities from Marine Biotechnology
 - FP7 Knowledge Based BioEconomy
 - ESF - Marine Board 2009
 - EC-US Biotechnology Task Force
 - OECD WPB
 - Korea March 2011 Workshop on the Challenges and Opportunities of Oceans and Coasts
 - Ostend Scoping Meeting - September 2011
 - Vancouver Global Forum on Marine Biotechnology Solutions for Ocean Productivity and Sustainability
 - Marine biotechnology: for ocean productivity and sustainability
 - Halifax 2013 BioMarine Business Convention



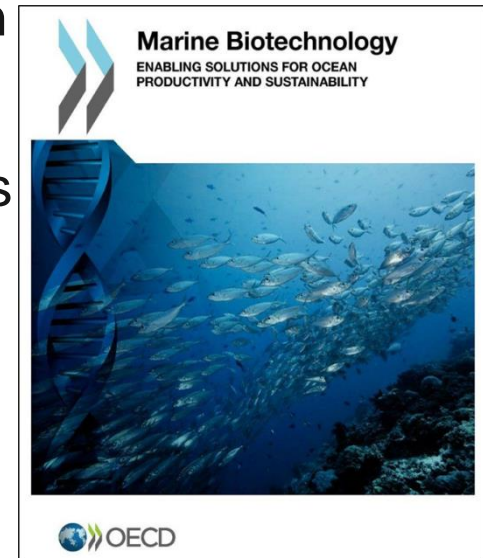


Marine Biotechnology: Enabling Solutions for Ocean Productivity and Sustainability

- Opportunities for development and exploitation
- Address global challenges
- Need for a governance framework for sustainable development of marine bioresources
- Link national jurisdictions to international agreements
- R&D infrastructure needs – international collaboration
- Need for stats and indicators – impact assessment
- Foster the uptake of marine biotech in other industries
- Need for environmental monitoring

<http://www.oecd.org/health/biotech/marine-biotechnology-ocean-productivity-sustainability.htm>

DOI: 10.1787/9789264194243





What is marine biotechnology ?

Four main areas covering marine bioscience and biotechnology

Organism-based Technology

- Bioprospecting
- Marine genome sequence and bioinformatics
- Metagenomics and other omics technologies

New Materials

- Drug discovery
- Industrial materials
- Enzymes
- Health supplements, nutraceuticals
- Biofuels and bioenergy
- Biorefining

Marine organism production

- Organism cultivation and collection
- Disease control and monitoring
- Marine biosafety
- Mass production e.g. seaweeds

Marine conservation

- Monitoring environmental change
- Pollution prevention and control
- Biodiversity conservation and ecosystem recovery



Drivers: marine biodiversity and discovery

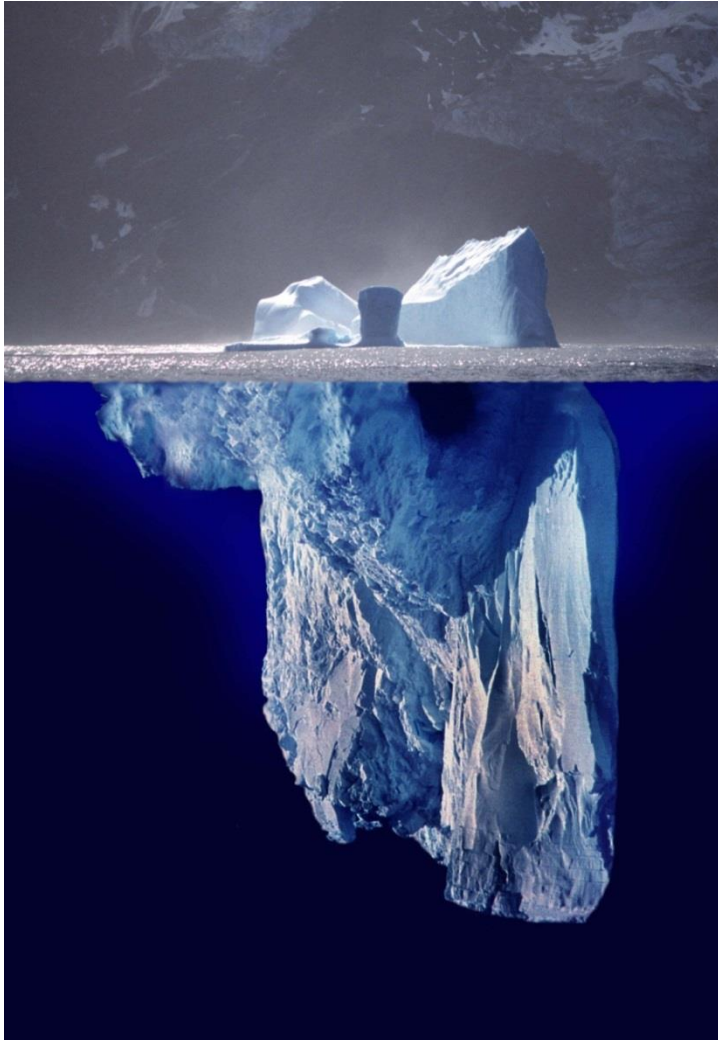
1/10 Gap

- In the Ocean the number of predicted species is about 10 times higher than the number of catalogued species (200,000).

1/100 Gap ?

- How big is the gap if we add meiofauna (animals < 0.5 mm), protists, and bacteria?
- Over 1600 new marine species discovered every year
- What about **genetic diversity** ?
- Our knowledge of marine biodiversity is minute

**< 1% of marine bacteria can be cultured
=> metagenomics**





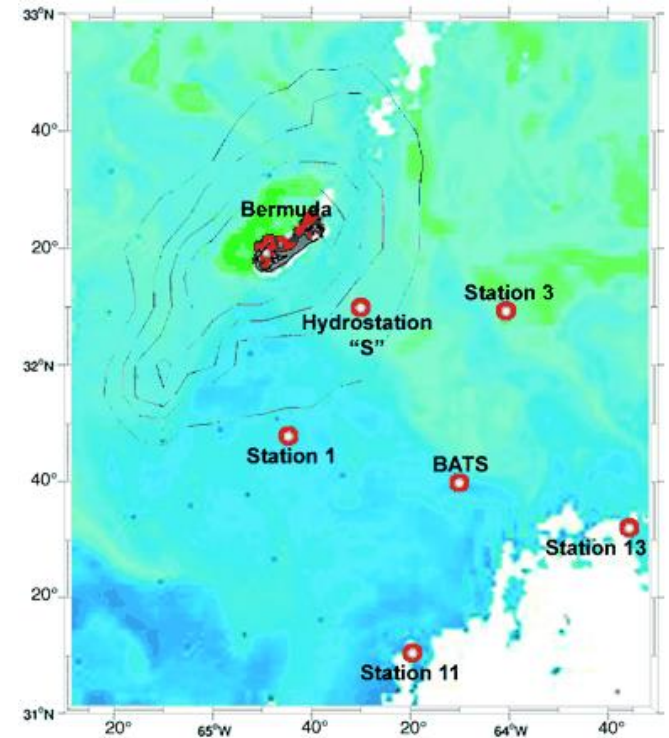
Large sampling expeditions

- **Global Ocean Sampling Expedition 2003-2004**

Venter *et al.* 2004

- assessing the genetic diversity in marine microbial communities
- 1800 species,
 - 148 new bacterial species
 - 1.2 million new genes.
 - substantial oceanic microbial diversity

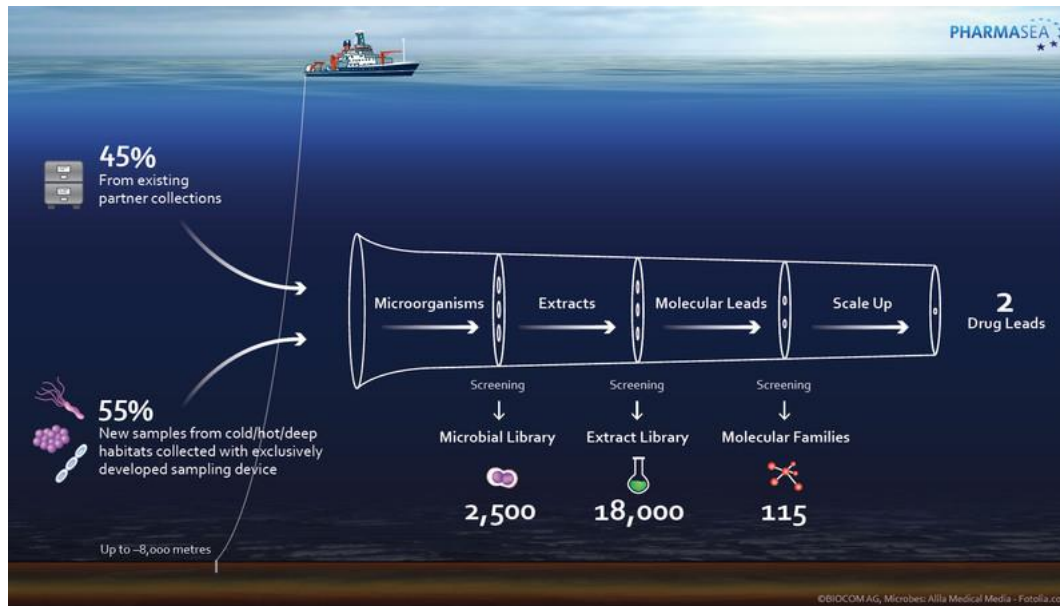
- **The Galathea 3 expedition 2006-2007**





Biodiscovery – novel bioactive compounds

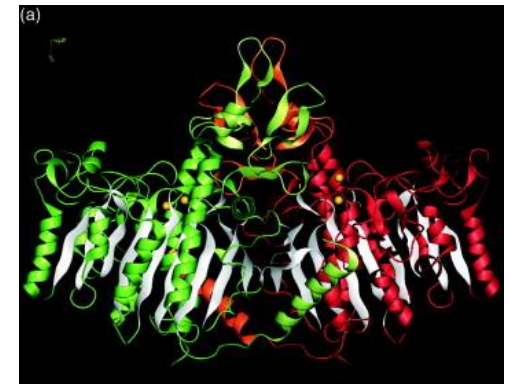
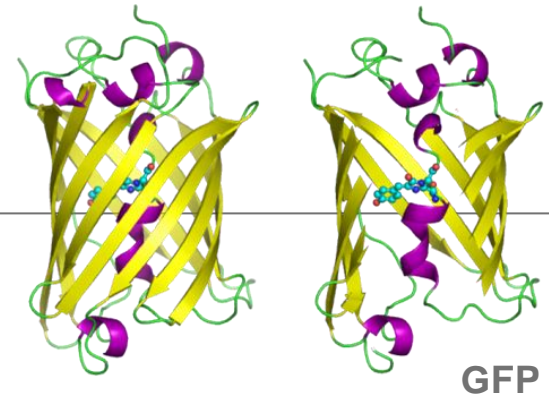
- **PharmaSea FP7: 24 partners – 13 countries**
 - marine genomics, biosynthesis, chemical structure analysis, legal
 - Biodiscovery R & D towards commercialisation
 - > 1,000 bacterial strains from many extreme locations
 - tested >12,000 extracts in >40,000 biological tests
 - bioactivity against infection and central nervous system diseases
 - new compounds have been identified





Biodiscovery potential

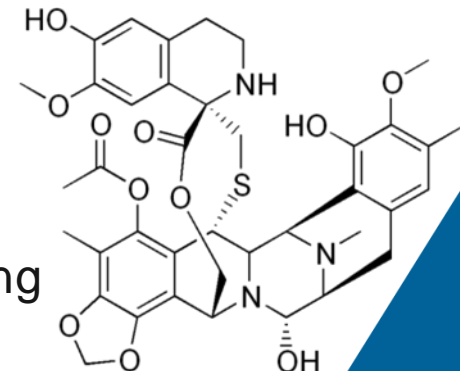
- New bioactive compounds – specific actions
 - New antibiotics
 - Pesticides, insecticides
 - Novel chemical families – novel targets
 - Enzymes
- Rational design cannot compete natural selection
- Production barriers



SAP

• BioTECHNOLOGIES

- ✓ Metabolomics : bioactive compounds identification
- ✓ Biochemistry : identification of biosynthetical pathways
- ✓ Structural biology : structural identification of compounds
- ✓ Synthetic biology : production system development
- ✓ Industrial biotechnology : improved biosynthesis - upscaling
- ✓ Genome editing : improving production



Trabectedin



Where is marine biotechnology just now ?

- Global market for Marine Biotechnology products and processes:
 - EUR 2.8 billion (2010)
 - cumulative annual growth rate of 4-5% ¹ to 10% in the coming years ²
 - by 2015 USD 4.1 billion (Global Industry Analysts, Inc. 2011)

Key factors driving market growth include growing interest from medical, pharmaceutical, aquaculture, nutraceutical and industrial sectors.
- US bio-based products : (2013)
 - direct sales of bio-based products < USD 126 billion,
 - indirect sales: USD 126 billion
 - induced sales: USD 117 billion (*// Bioeconomista, 2015*).
- Industrial enzymes market:
 - 2014: valued at USD 4.2 billion
 - by 2020: USD 6.2 billion
 - CAGR of 7.0% from 2015 to 2020 (ReportLinker, 2015).

1 European Science Foundation, Marine Board (2010). Position Paper 15.

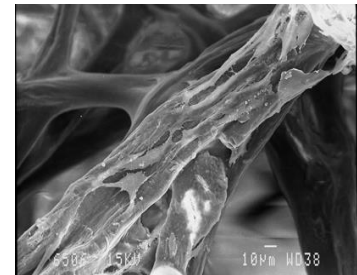
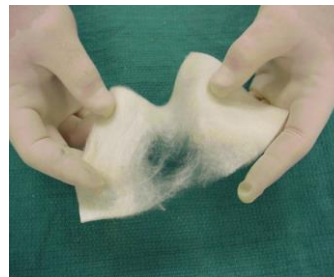
2 Allen & Jaspers (2009). *Industrial Biotechnology* 5, 77-83.



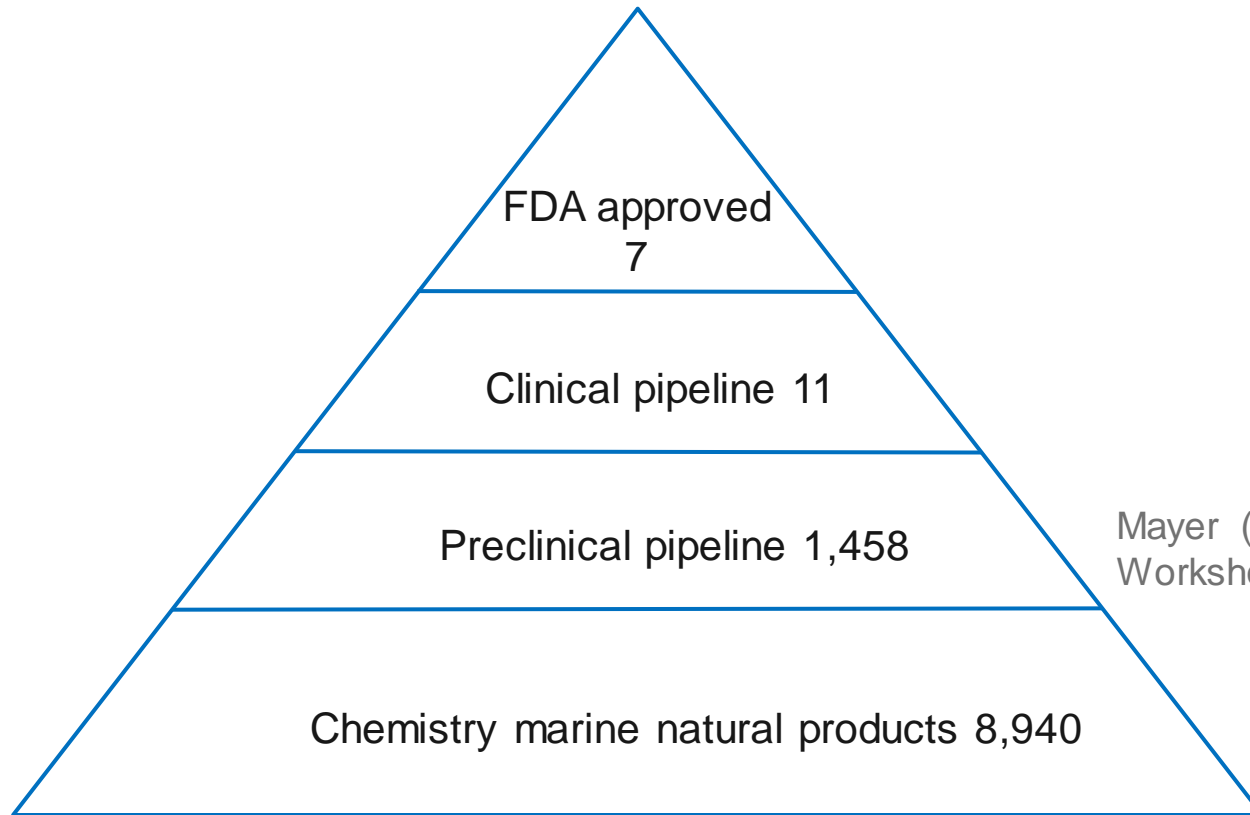
Market situation - health products

- **Functional foods** (inc. nutraceuticals) growing from USD175 billion in 2013 to reach USD 230 billion by 2014 ¹
- **Cosmeceuticals** - forecast to reach global sales of USD 42 billion by 2018 ²
- **Biomaterials** – market for orthopaedic, cardio-vascular and wound care estimated to be worth USD 64.7 billion in 2015 ³
- **Medical device technologies** market worth USD 454.3 billion by 2014 (inc USD 110.8 billion drug delivery) ⁴
- **Bone replacement** – growing at 7 percent per annum and valued at USD 2 billion ⁵

Dermot Hurst, 2014



Global marine pharmaceutical pipeline, 2012



Mayer (2012). OECD Marine Biotechnology Workshop, Vancouver, May 2012

- Pharmacia
- Mitsubishi Kagaku Medical
- Kyowa Hakko Kogyo
- Sankyo Pharma
- Genencor International
- Pfizer Inc.
- Lonza
- BASF
- Merck & Co
- Bristol-Myers Squibb



Marine pharmaceuticals preclinical pipeline 1998-2011 over 1000 compounds

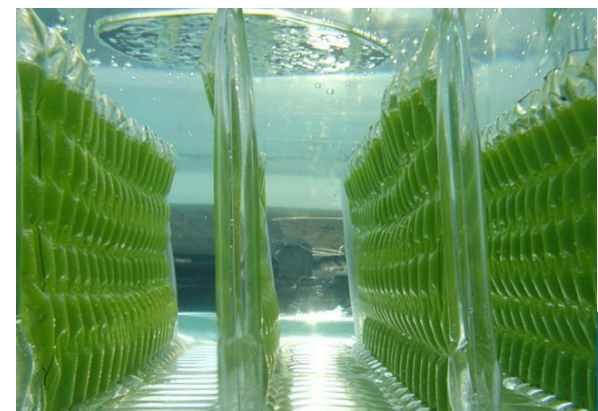
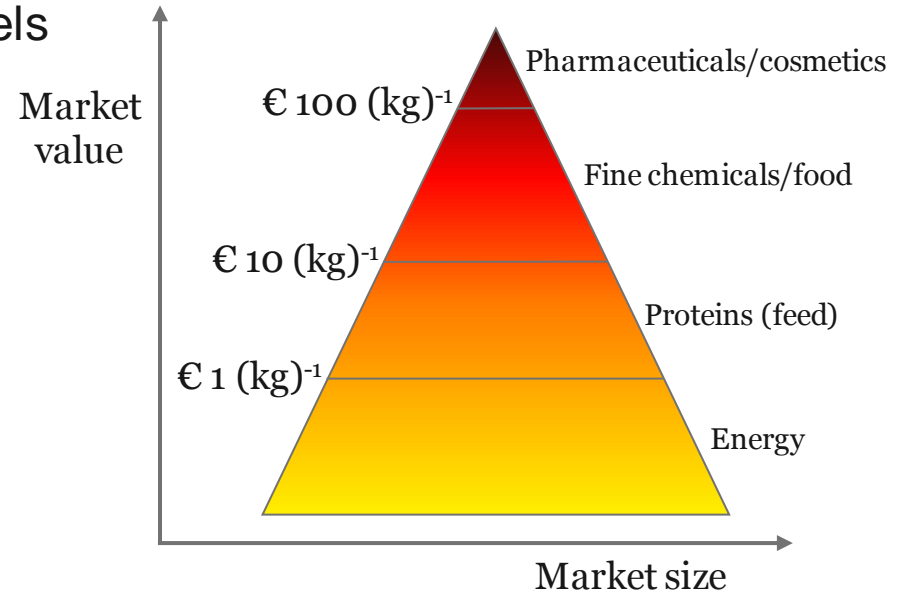
- Antitumour
- Antibacterial
- Antifungal
- Antiviral
- Antimalarial
- Antituberculosis
- Antiprotozoal
- Anticoagulant
- Cardiovascular
- Anti-inflammatory
- Immune system
- Nervous system
- Variety of molecular targets
 - enzymes
 - receptors



Algae: disruptive technology ?

biodiesel, bioethanol, biogasoline,
biomethanol, biobutanol and other biofuels

Crop	Oil yield [gallons (acre) ⁻¹]
Corn	18
Cotton	35
Soybean	48
Mustard seed	61
Sunflower	102
Rapeseed	127
Jatropha	202
Oil palm	635
Algae	10,000



Source: adapted from Pienkos (2009)



Value comparisons for algal products

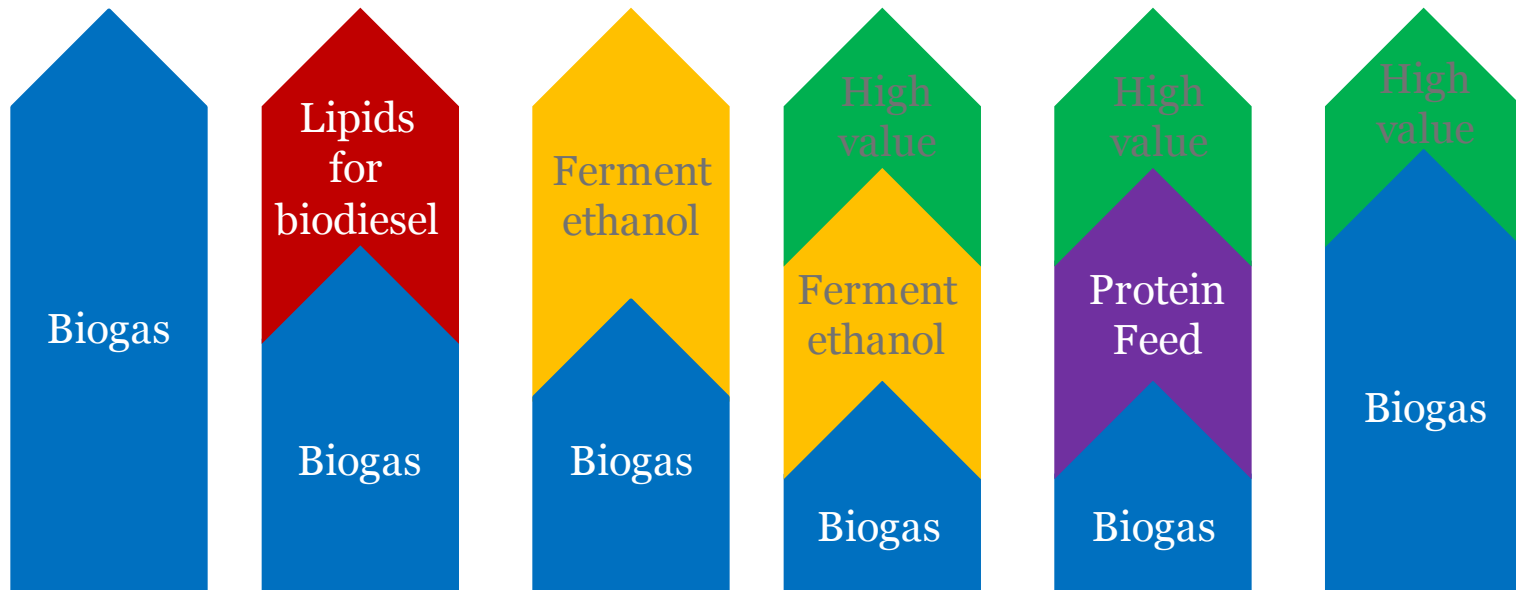
Molecule	Photons required	USD per photon	Market size (per annum)
Octane	100	1	7.5 B barrels (US)
Lysine	92	5.9	700,000 tonnes (WW)
Phenylalanine	96	32	11,000 tonnes (WW)



Adapted from Ducat et al. (2011). *Trends in Biotechnology* 29, 95-103.



Algal integrated biorefinery concept



- Microalgae are rich in PUFA - extracted before esterification for biofuels production
- PUFA are vegetable alternatives to fish oils and oils rich in Omega-3 fatty acids
- High value products made in an integrated microalgae biorefinery that also produces biodiesel
- Co-locate with source of CO₂, such as power stations ?
- Integrate with aquaculture? i.e. finfish, mussels and algae production at one location



ESFRI - Infrastructure for marine biotechnology

- **EMBRC**, the European Marine Biological Resource Centre ;
 - research and training facilities at leading marine research stations
 - access to marine biodiversity, its associated meta-data and extractable products
 - data-sharing and standardisation of data gathering and storage
- **ELIXIR**, the European Life-Science Infrastructure for Biological Information ; and
 - collection, storage, annotation, validation, dissemination and utilisation of biological data
 - open access, standardised data, solutions for storage and computing infrastructure, training and tools
- **MIRRI**, the Microbial Resource Research Infrastructure
 - network of microbial domain Biological Resource Centres (BRC)
 - common standards, ensure the validation of sequence data



Global initiatives

- **Global Biodiversity Information Facility** – GBIF is an international open data infrastructure, funded by governments.
 - Not exclusively marine biodiversity, but has been used for marine conservation planning
- **Census of Marine Life** – CoML: assess the diversity, distribution and abundance of marine life: now and in the future:2 000
 - Marine component of GBIF
 - Linked to iBOL
- **International Barcode of Life Project - iBOL** – and the **Barcode of Life Data Systems** – BOLD
 - The Fish Barcode of Life Initiative (FISH-BOL)
 - The Marine Barcode of Life campaign (MarBOL)
 - The Sponge Barcoding Project
 - The Polar Barcode of Life campaign (PolarBOL)



Other infrastructures

US

- The **Harbour Branch Oceanographic Institute** – HBOI
 - Centre of Excellence in Biomedical and Marine Biotechnology: the scientific potential of the oceans for drug discovery and develop biotechnology applications: 50000 samples of marine invertebrates and isolates of marine microbes for drug discovery
- The **Developmental Therapeutics Programme (DTP) - Natural Products Repository** NIH National Cancer Institute at Frederick
 - 170,000 extracts from samples of more than 70,000 plants and **10,000 marine organisms** collected from more than 25 countries, plus more than 30,000 extracts of diverse bacteria and fungi.
 - Indo-Pacific region, the Australian Institute of Marine Science, the University of Canterbury, New Zealand, and the Coral Reef Research Foundation
 - screened against the NCI human tumor cell line assay for potential anticancer activity : 4,000 natural-source extracts have shown in vitro activity against human cancer cells
 - Natural Products Repository: a national resource, available to qualified organizations through the Open Repository Program and the Active Repository Program. Access to these programs are subject to signing a Material Transfer Agreement protecting the rights of all parties



- **The Ocean Biotechnology Center and Repository (OBCR)**

@ National Center for Natural Products Research (University of Mississippi).

cataloguing and analysis of extracts derived from marine organisms:
> 2000 extracts tested for antibiotic, anticancer, and antimalarial activity

Sampling in Hawaii, Alaska, Puerto Rico, Guam, Saipan, and American Samoa: shallow reefs and deep sea

Over 10% of the repository samples have been flagged for follow-up research efforts (this compares favorably to the 0.5% "hit-rate" reported for terrestrial plants by the NCNPR).



Other infrastructures

NO, CA

- **Marbank, NO**
 - co-ordinate a network of marine collections
 - provide easy access for national and international academia and industry to marine biodiversity and the associated data.
 - bioprospecting
 - Arctic, sub-Arctic and boreal habitats varying from the intertidal zone to the deep seas
 - linked to international collaboration partners and is member of ESBB (European, Middle Eastern and African Society for Biopreservation and Biobanking, a regional chapter of ISBER) an international society for the biobanking of human and non-human biological materials
- **Centre of Expertise in Cold-water Coral and Sponge Reefs (CECCSR), CA**
 - Developing tools and approaches to improve coral and sponge conservation in Canada;
 - Providing strategic advice to senior management; and
 - Supporting regional, national, and international efforts for coral and sponge conservation



Other infrastructures

KR

- **The Marine Biotechnology Programme and Research Infrastructure**
 - Korea Institute of Ocean Science and Technology (KIOST)
 - Marine and Extreme Bioresource Collection, a biobank collection of marine and extremophile organisms that includes marine microorganisms and marine nematodes. databank containing genomic, metagenomic and other omics information of marine organisms is connected to this biocollection
 - Marine Biotechnology Research Centre (MBRC): Genome sequence information of marine bioresources: Antarctica and deepsea Pacific Ocean
 - to discover and develop new physiologically marine bioactive substances and new biomaterials from marine origin
 - Bioenergy
 - Korea Polar Research Institute – KOPRI
 - genomics data; polar (marine) microbial collection
 - Korea South Pacific Ocean Research Center - KSORC



Other infrastructures: Japan

- **Marine Biotechnology Institute Co-Culture Collection** hosted at the NBRC, the National Biological Resource Centre.
- The **National Bioresource Project - NBRP** aims to create systematic and complete collections of all Japan's biodiversity, including from marine resources .
- **National Institute of Technology & Evaluation Department of Biotechnology**
 - the Genome Analysis Centre (NGAC)
 - the Biotechnology Development Centre (NBDC)
 - Patented Micro-organisms Depository (NPMD).



Huge potential






Bridge from promise to delivery



Promises



Industry



THANK YOU

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