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The Full Value of Marine Genetic Resources (MGR)



Fig 1 A brittle star living commensally on a deep-sea octocoral.
NOAA OER



Fig 2 A tube-dwelling anemone or cerianthid.
NOAA OER

Marine genetic resources, derived from the immense biodiversity of the ocean, not only represent an alluring potential source of fundamental scientific discovery and commercial bioproducts – they provide an integral part of the global systems that make Earth habitable.

The hidden operating system of our planet

The ocean is brimming with life. In addition to an estimated 2.2 million species of marine animals,¹ the global ocean may contain up to a *trillion* different types of microorganisms.² In aggregate, this diversity provides essential ecosystem services that sustain the planet, support whole industries (including fisheries), and have supported specific societal needs (including medical and pharmaceutical applications). Unveiling the biological processes that underpin the real value of this collective genetic diversity, and the role it plays in ocean and planetary health, highlights the wide-reaching benefits of genetic diversity.

Genetic material has environmental, economic, scientific and societal value

The precise meaning of marine genetic resources (MGR) and other related terms can be murky. The 1992 *Convention on Biological Diversity* defines genetic resources as "genetic material of actual or potential value". This value, can be considered in environmental, economic, societal and scientific terms (see Global Plan of Action for the Conservation, Sustainable Use and Development of Forest Genetic Resources³) and resides in ecosystems and their associated biodiversity (see Nagoya Protocol⁴). The value of genetic resources is based on the many ways in which biological materials (also referred to as biomolecules) function and how organisms interact to transform chemicals and change their environments.

Genes in action: from biomolecules to biological systems

Marine genetic resources could be derived from a range of biological materials across a continuum of spatial scales - from kilometer-scale ecosystems to microscale individual organisms and their nanoscale gene products (see Figures 3 and 4).

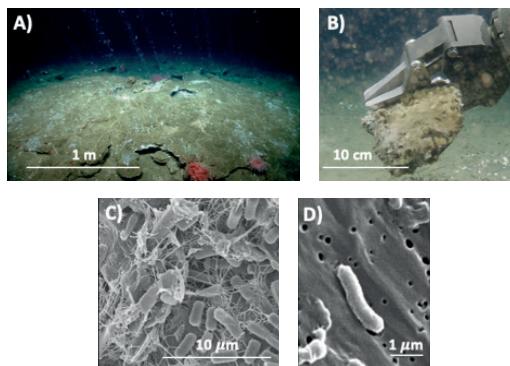


Fig 3 MGR derive from life-forms across a range of scales (A) Ecosystems; (B) Habitats (e.g. rock, or soft bottom environment); (C) Communities of microbes; (D) Individual cells.

(Image credits: (A, B) NOAA; (C, D) Lewis Lab, Northeastern University).

Ecosystems include animals, microorganisms (*Bacteria*, *Archaea*, and viruses), and their physical and chemical surroundings. Habitat components such as rocks, sediment, sinking particles, and the water itself contain abundant communities of microbes. Single celled microbes connect with larger organisms through food webs – all the way to megafauna such as fish and whales. All cells – those that comprise microbes and animals alike – possess biomolecules with the potential to cause molecular transformations (Figure 4).

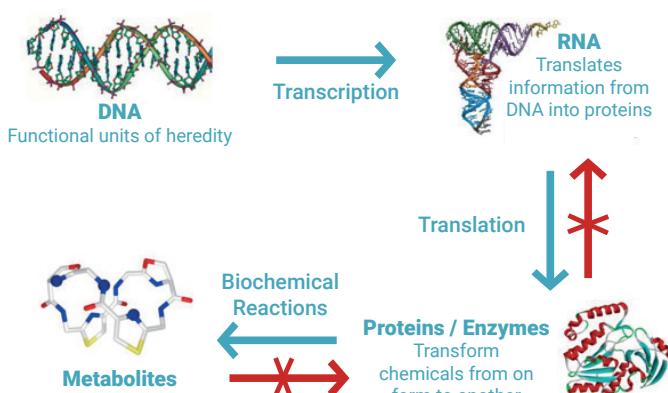


Fig 4 DNA is the cell's master "instruction manual"; when the time is right, segments of the DNA ("genes") are read off ("transcribed") to build a corresponding piece of RNA, which ultimately helps to create a protein. Proteins are the functional unit of the cell, micro-machines used for cell repair or to make hormones, for example. By turning one chemical into another, proteins make metabolites, or biochemical derivatives that are generally more efficient and expansive than industrial processes. Unfortunately biomolecule data cannot be "reverse engineered"; knowing a metabolite's formula or a protein's sequence is insufficient to predict the sequence of the underlying gene. Typically, scientists store genetic/genomic information in databases (e.g., GenBank), where it is referred to most commonly as *in silico* or digital sequence information. (Further information on these types of data and their uses can be found at the Convention on Biological Diversity's Synthetic Biology report.⁵

Benefits of Marine Genetic Resources

→ Ocean health and ecosystem function:

Biological stability depends on genetic diversity. Marine biological processes provide a range of ecosystem services that include nutrient cycling, climate regulation, fisheries production and cultural significance.⁶ These services are essential when considered together, and may also be important at smaller spatial scales; this means that a precautionary approach to MGR extraction, particularly in the case of rare or fragile organisms (e.g., microbial communities surrounding seafloor hydrothermal vents) is key. Genetic diversity provides systems with the potential to adapt to changing conditions (including climate change) by maintaining a greater range of possible response 'options'⁷. Utilisation of MGR for non-commercial purposes has allowed researchers to better understand how ecosystems function and how they respond to various stressors, with important implications for evaluating who's who (taxonomy) and conservation research in the microbial world.⁸

→ **Biotechnology:** At the ecosystem scale, society can utilize multi-species microbial communities (for example, to consume methane for potential biofuel production⁹) and thus make bioindustrial¹⁰ processes more resilient, stable,¹¹ and efficient.¹² At smaller scales, raw extracts from marine organisms, individual genes, proteins, and the chemicals they generate have increased crop resilience to disease, speeded up industrial reactions,¹³ and contributed new medicines, pharmaceuticals, personal care products, and nutraceuticals.¹⁴ For example, a compound (Plitidepsin) isolated from a tunicate that lives in the Mediterranean Sea shows promise as an anticancer agent;¹⁵ a molecule produced by deep-sea organisms screens the harmful light rays that cause skin wrinkles;¹⁶ and insertion of genes from marine phytoplankton into commercial crops enhances omega-3 fatty acid content.¹⁷

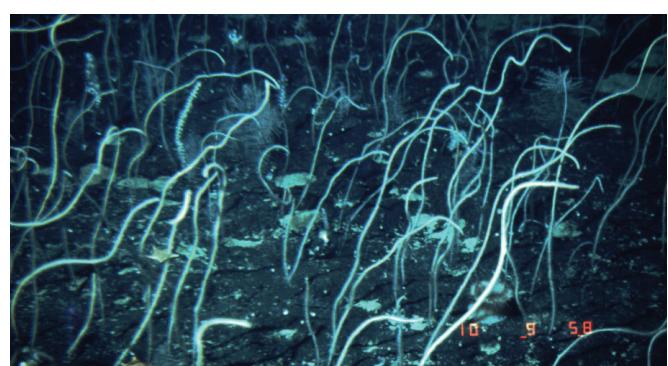


Fig 5 East Pacific seamount coral garden;
Credit: Lisa Levin

Thinking ahead

The 'actual or potential value' of genetic material depends on natural processes of biological systems and their components (e.g., communities of organisms, individual cells, genes, proteins, or chemical products). Maintaining ocean ecosystem services and our broader ability to obtain food, clean air, and a stable climate depends heavily on marine genetic diversity. Biological processes influence the health and efficiency of the ocean "operating system", including its ability to adapt to changing conditions, extending the true value of genetic diversity well beyond commercial applications.

Assessing the value of genetic diversity for commercial applications is notoriously difficult. Transgenic canola crops, for instance, which provide widely used and comparatively inexpensive cooking oil, utilize multiple enzymes - of both marine and terrestrial origin - which function in unison to improve crop yield. The innovation and resulting value therefore do not utilize unique genes of a single species, but rather several species. Likewise, the development of new pharmaceuticals faces extraordinarily high failure rates coupled with high investment costs.

Uncertain legal and regulatory landscapes can stifle long-term investments in MGR development and simultaneously limit collaborative research efforts to understand the ocean's underlying ecosystem services. BBNJ negotiations offer a unique opportunity to mobilize the scientific and private sectors in support of a clear legal framework, ensuring that policy keeps pace with rapid scientific developments.¹⁸



Fig 6 An undescribed species of hydromedusae seen at over 4000 metres close to the Mariana Trench. NOAA OER

Suggested Reading:

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10. A biological system that has been scaled up or is being used for industrial purposes (e.g., Fuelzyme®-alpha-amylase which is an enzyme used for starch liquefaction in the production of fuel ethanol - <http://www.synbioproject.org/cpi/applications/fuelzyme-alpha-amylase/>)
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15. Le Tourneau, C., Faivre, S., Ciruelos, E., Domínguez, M. J., López-Martín, J. A., Izquierdo, M. A., ... & Raymond, E. (2010). Reports of clinical benefit of plitidepsin (Aplidine), a new marine-derived anticancer agent, in patients with advanced medullary thyroid carcinoma. American journal of clinical oncology, 33(2), 132-136.
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18. Wynberg, Rachel, and Sarah A. Laird. "Fast science and sluggish policy: the herculean task of regulating biodiscovery." *Trends in biotechnology* 36.1 (2018): 1-3.

Fig 5 The echinoids *Brisaster latifrons* attracted by bacterial mat, 417-429 m, Chukotka slope, Bering Sea.
Copyright: National Scientific Center of Marine Biology Far East Branch Russian Academy of Sciences, Vladivostok, Russia

Fig 6 Grenadier at 870m in the Davis Strait, west Greenland.
Courtesy of Stephen Long, Zoological Society of London, UK

Fig 7 Variety of deep-sea life in the north-east Atlantic.
Courtesy of the NERC funded Deep Links Project - Plymouth University, Oxford University, BGS, JNCC

Fig 8 Brisingid and corals.
Courtesy of Malcolm Clark, NIWA, NZ



ABOUT DOSI

The Deep-Ocean Stewardship Initiative seeks to integrate science, technology, policy, law and economics to advise on ecosystem-based management of resource use in the deep ocean and strategies to maintain the integrity of deep-ocean ecosystems within and beyond national jurisdiction.

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