SustainaBlue

HEIs stands for Higher Education Institutions

Introduction to Marine Bioprospecting

Co-funded by the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Project: 101129136 — SustainaBlue — ERASMUS-EDU-2023-CBHE

UNIVERSITAS INDONESIA

Veritas, Probitas, Iustitia

SustainaBlue
HEIs stands for Higher Education Institutions

PROJECT PARTNERS

Malaysia

Universiti Malaysia Terengganu UMT

USM Universiti Sains Malaysia APEX

Persatuan Kemajuan Akuakultur Malaysia — Malaysia Aquaculture Development Association

Indonesia

Universitas Indonesia — Veritas, Probitas, Iustitia

ITS Institut Teknologi Sepuluh Nopember

Greece

Πανεπιστήμιο Αιγαίου — University of the Aegean

symplexis

AEGEAN rebreath

Cyprus

University of Cyprus Oceanography Centre

Center for Social Innovation www.csicy.com

Co-funded by the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Project: 101129136 — SustainaBlue — ERASMUS-EDU-2023-CBHE

SustainaBlue
HEIs stands for Higher Education Institutions

Content

Co-funded by
the European Union

Learning Objectives

- ❑ Define marine bioprospecting
- ❑ Identify target marine organisms
- ❑ Understand the bioprospecting process
- ❑ Recognize industrial applications
- ❑ Discuss legal and ethical issues

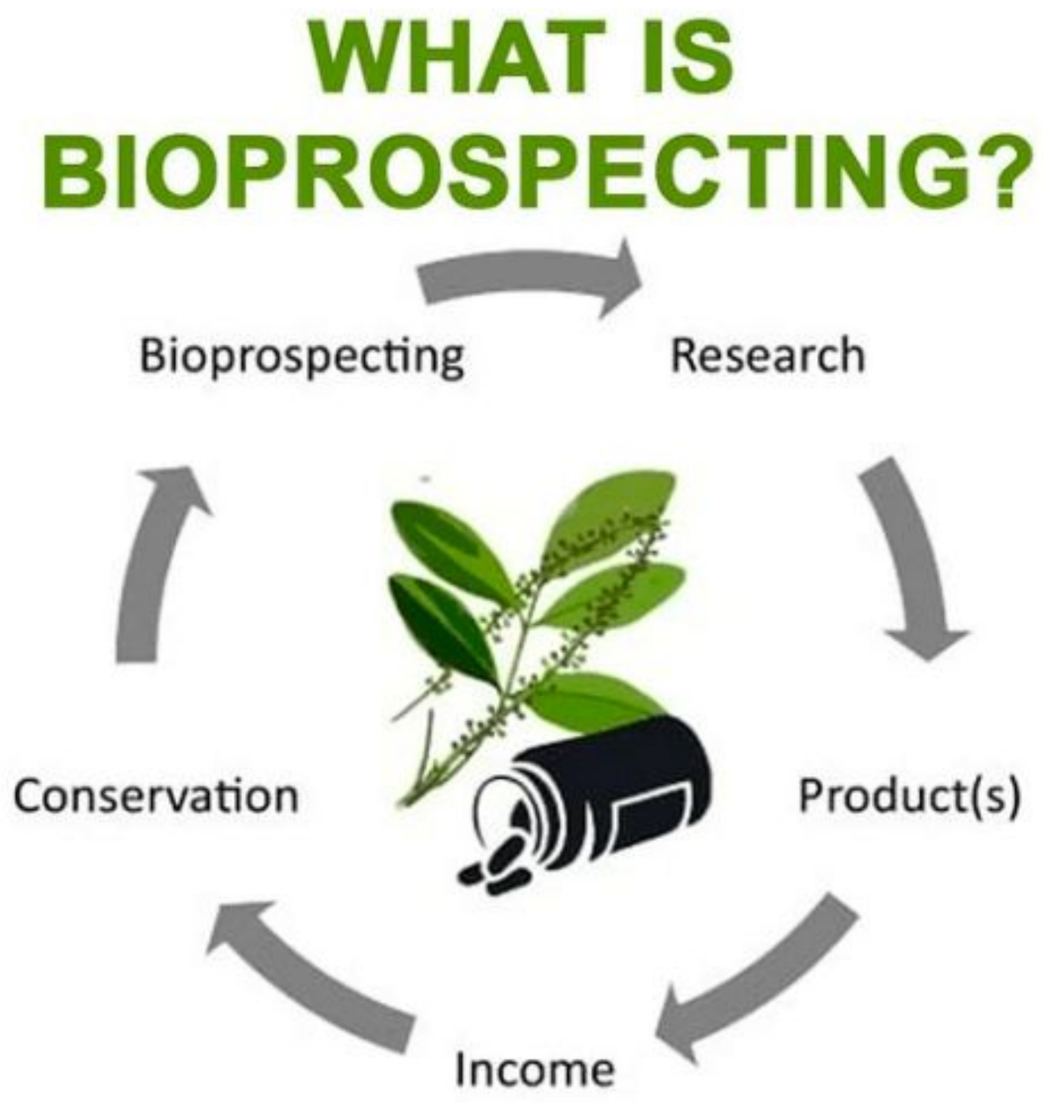
SustainaBlue
HEIs stands for Higher Education Institutions
Co-funded by the European Union

What is Bioprospecting?

- **Bioprospecting:**
  Search for bioactive compounds in natural organisms

- Bioprospecting is nature's treasure hunt—searching for new biological compounds that can benefit society. Done responsibly, it fosters scientific innovation, environmental conservation, and fair collaboration with communities that hold traditional ecological knowledge.

(Skirycz *et al.*, 2016)



(Source: Skirycz *et al.*, 2016.)

Co-funded by the European Union

What is Marine Bioprospecting?

- Marine bioprospecting **focuses on ocean biodiversity for novel compounds**
- Marine bioprospecting is the process of exploring the marine environment for unique genes, molecules, and organisms with potential uses in various industries like pharmaceuticals, cosmetics, medicine and food production.
- This process is driven by the vast and relatively unexplored biodiversity of the ocean, which holds promise for novel compounds, materials, and biotechnological solutions.

(Flemsæter, 2020)

(Source:https://www.asiaone.com/world/map-worlds-uncharted-ocean-beds-takes-shape-despite-crisis)

Co-funded by the European Union

Why the Oean?

- **Exploring marine bioprospecting is crucial** because the oceans are a vast and largely unexplored source of unique genes, molecules, and organisms with potential for groundbreaking applications in various fields. (Flemsæter, 2020)
- The ocean covers 70% of Earth and home to 90% of the biosphere
- The ocean has an extreme environment which results in the discovery of unique compounds.
- The ocean has high biodiversity in species and ecosystem (reefs, vents, etc.)

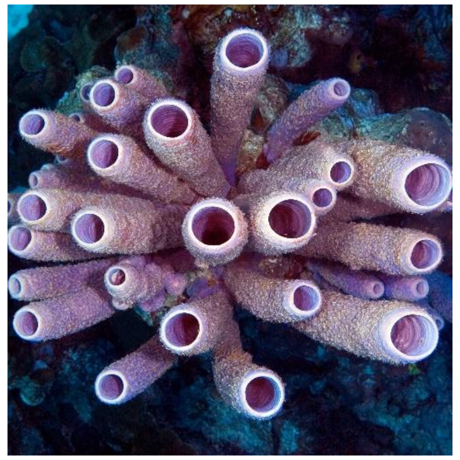
(Source:https://www.asiaone.com/world/map-worlds-uncharted-ocean-beds-takes-shape-despite-crisis)

Co-funded by the European Union

SustainaBlue
HEIs stands for Higher Education Institutions

Marine Organisms of Interest

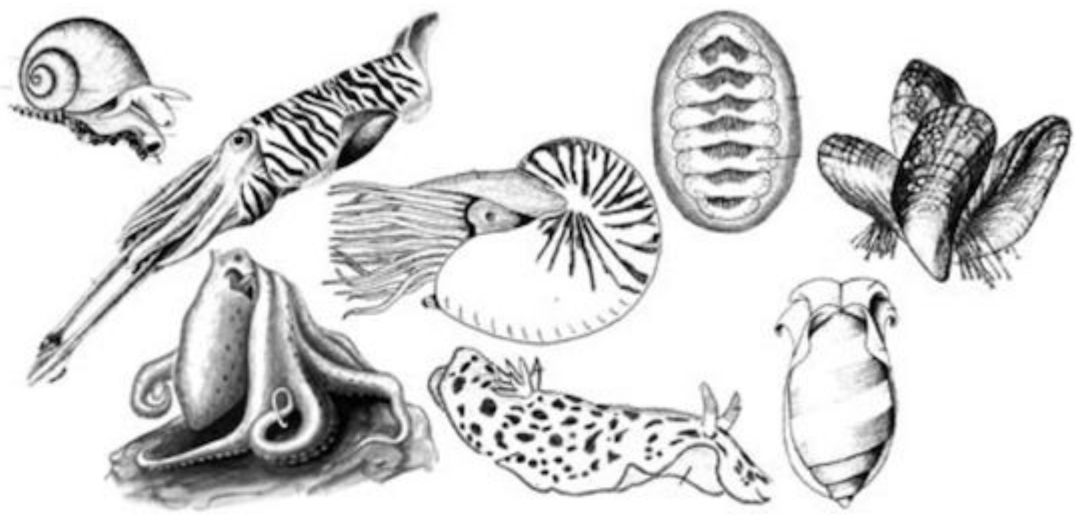
- Sponges



- Cyanobacteria

- Algae

- Tunicates, Mollusks



- Marine fungi & actinomycetes

Co-funded by
the European Union

Steps in Marine Bioprospecting

Marine bioprospecting involves several key steps:

1. Sample collection
2. Isolation and screening of bioactive compounds
3. Characterization and testing
4. Product development and commercialization.

This process aims to discover and utilize valuable biological resources from marine organisms for various applications, including pharmaceuticals, nutraceuticals, and industrial products.

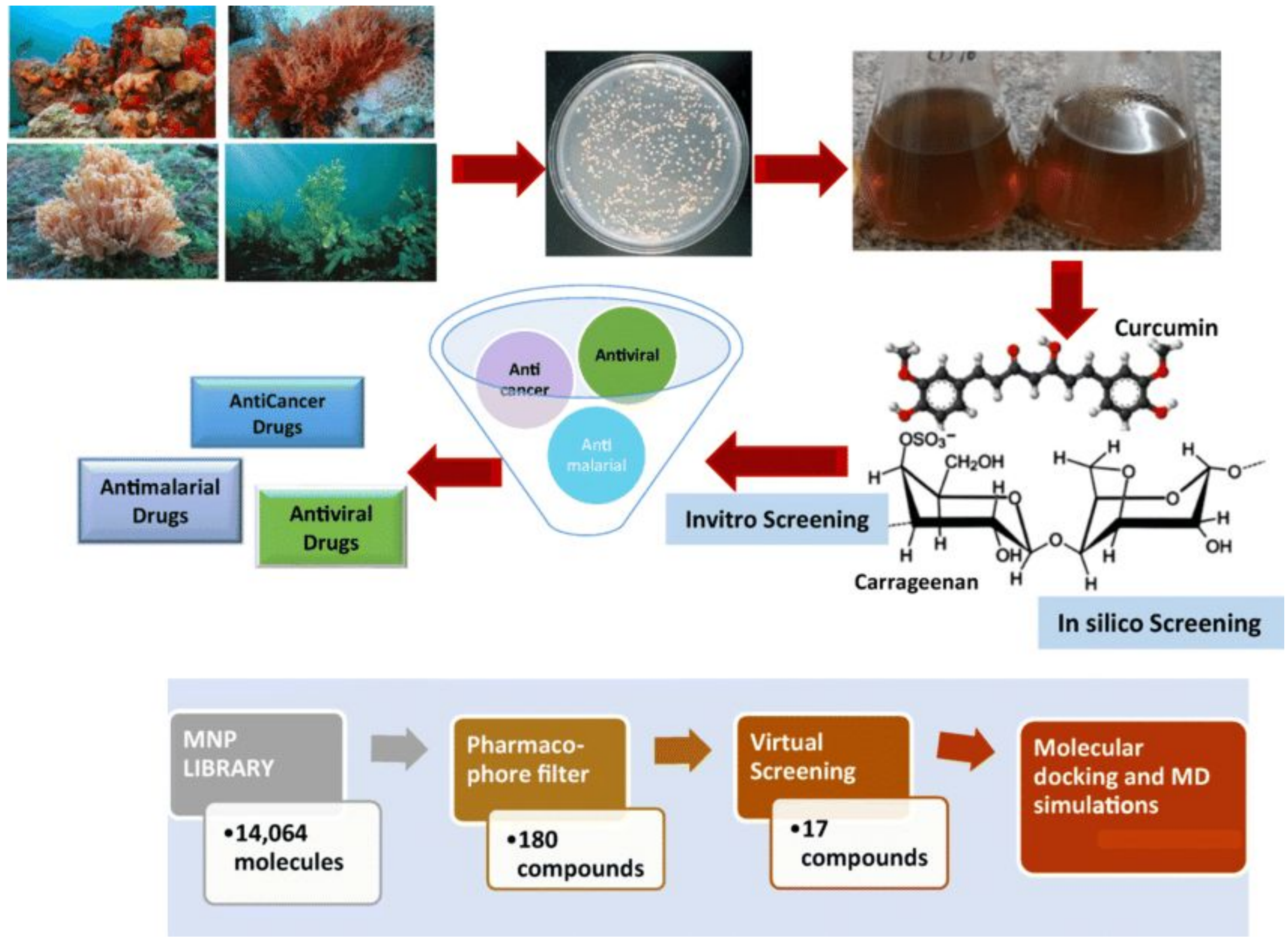
Co-funded by
the European Union

Steps in Marine Bioprospecting

1. Sample Collection:
This initial phase involves the exploration and collection of marine organisms from diverse habitats like the deep sea, coastal areas, and even oil reservoirs. The goal is to gather a wide range of biological samples, including microorganisms, plants, and animals.

2. Isolation and Screening:
Once samples are collected, they are brought to the lab for further analysis. Scientists isolate and culture microorganisms, and then screen for bioactive compounds, which are molecules that exhibit a desired biological activity. This screening process often involves various bioassays to identify compounds with potential pharmaceutical or industrial applications.

(Singh *et al.*, 2021)



(Source: Singh *et al.*, 2021)

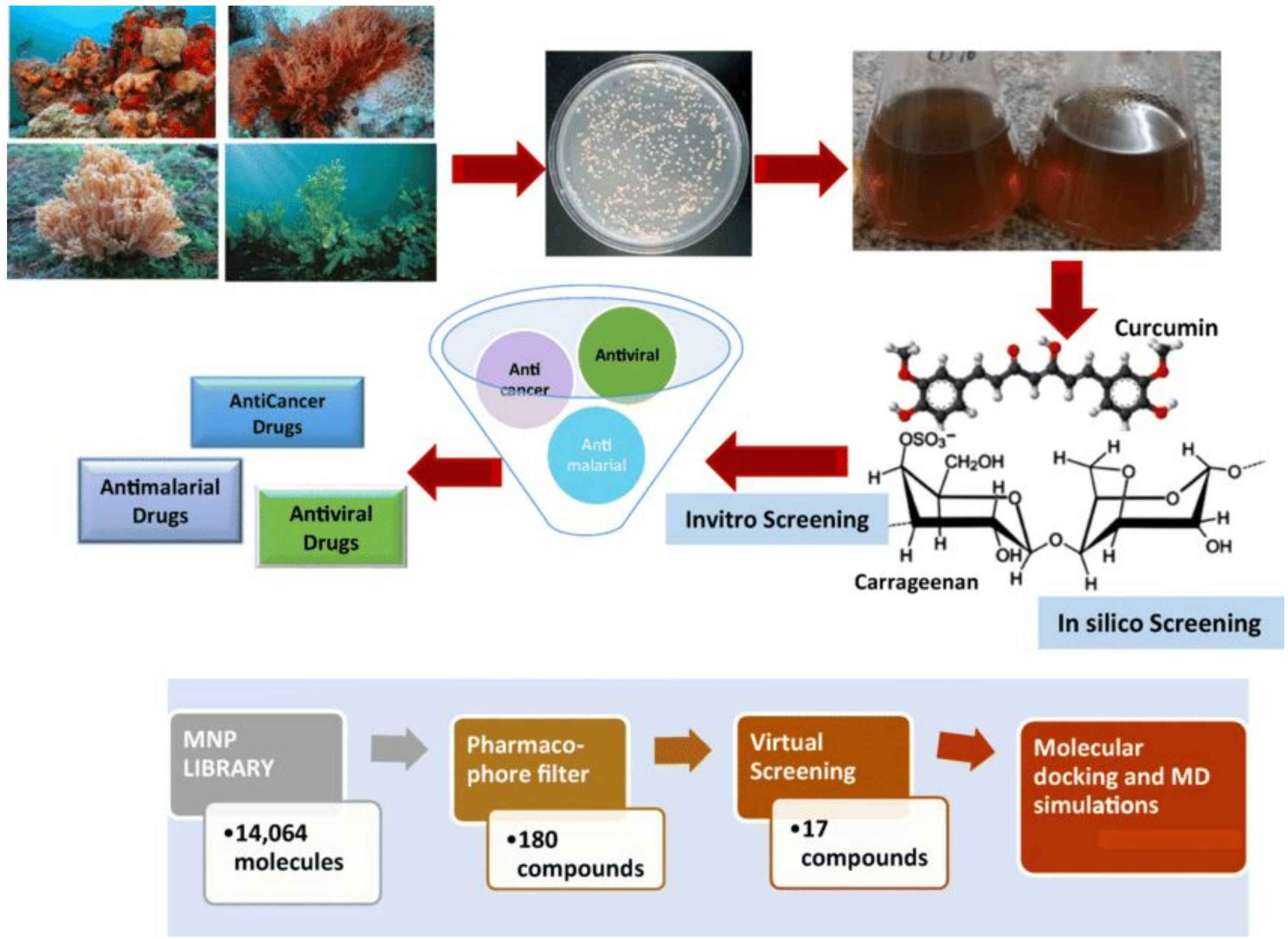
Co-funded by the European Union

Steps in Marine Bioprospecting

3. Characterization and Testing:
After identifying promising compounds, they are characterized to determine their chemical structure, properties, and biological activity. Further testing is conducted to assess the compound's efficacy, safety, and potential for development into a marketable product.

4. Product Development and Commercialization:
This final phase involves scaling up the production of the bioactive compound, securing intellectual property rights (patents), and developing the product for market. This stage also includes marketing and sales of the final product.

(Singh *et al.*, 2021)



(Source: Singh *et al.*, 2021. Fig.3)

Co-funded by the European Union

SustainaBlue
HEIs stands for Higher Education Institutions

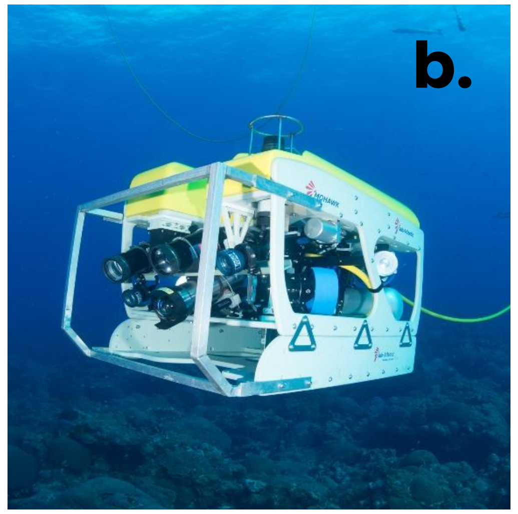
Techniques Used in Marine Bioprospecting

1. Sampling and Collection

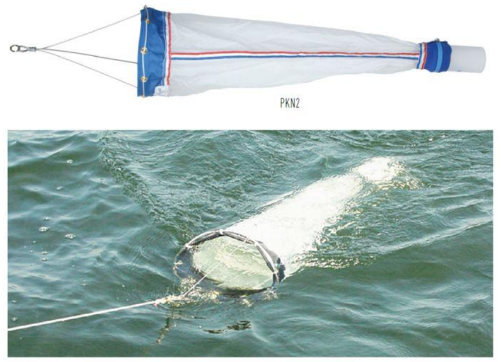
This is the first step, gathering biological material from the ocean.

Techniques:

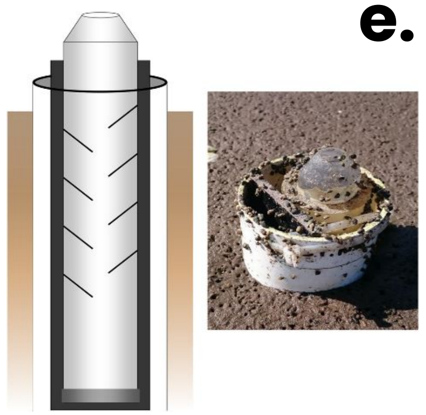
a. Scuba Diving: For shallow-water organisms (e.g., sponges, algae, tunicates).
b. ROVs (Remotely Operated Vehicles): To access deep-sea organisms without human divers.
c. Sediment/Core Sampling: For benthic microbes or sediment-associated organisms.
d. Plankton Nets: To collect free-floating microbes, phytoplankton, or zooplankton.
e. Settlement Traps or Panels: For recruiting colonizing biofoulers like bacteria, tunicates, barnacles.



d.



e.

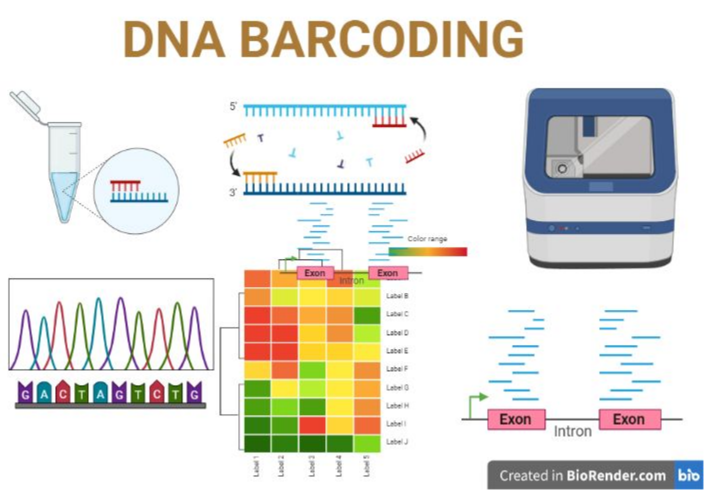


Co-funded by the European Union

Techniques Used in Marine Bioprospecting

2. Taxonomic Identification
It's crucial to know what organism is being studied.
Techniques:

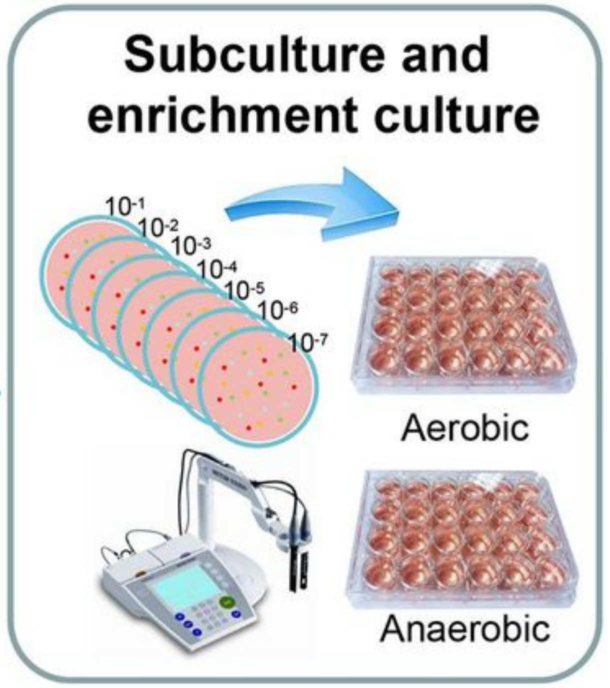
a. Morphological Analysis: Classical taxonomic keys based on shape, structure.
b. DNA Barcoding: Uses specific gene sequences (e.g., COI, 16S rRNA) to identify species.
c. Metagenomics: To analyze DNA directly from environmental samples, especially for microbes that can't be cultured.



(Source: https://sciencevivid.com/dna-barcoding/)

3. Culturing and Isolation (Chang, *et al.*, 2019)
Many organisms (especially microbes) must be cultured to study their products.
Techniques:

a. Selective Media: Culturing bacteria/fungi from marine sediments or organisms.
b. Co-culturing: Stimulates production of certain compounds by mimicking interactions in nature.
c. Enrichment Cultures: Favor the growth of desired functional groups (e.g., actinomycetes).



(Source:Chang *et al.*, 2019)

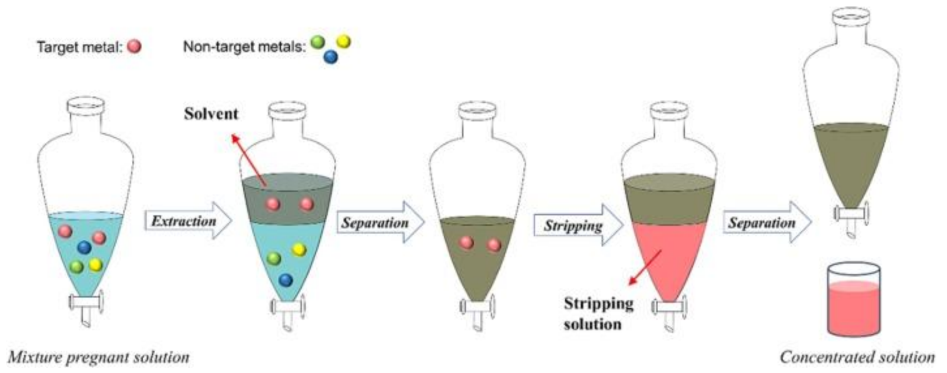
Co-funded by the European Union

Techniques Used in Marine Bioprospecting

SustainaBlue
HEIs stands for Higher Education Institutions

4. Extraction of Compounds (Erkey, 2011)
Biomolecules are extracted for testing.
Techniques:

a. Solvent Extraction: Using ethanol, methanol, hexane, etc. to extract different types of compounds.
b. Solid-Phase Extraction (SPE): Concentrates and purifies compounds from liquid samples.
c. Supercritical Fluid Extraction (SFE): A green chemistry technique using CO_2 for extraction.

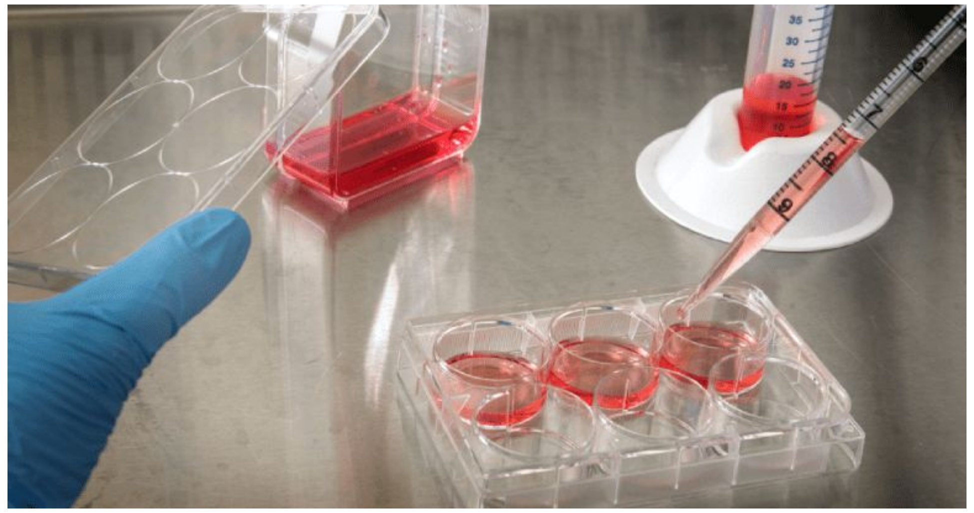


(Source: Erkey, 2011)

5. Bioactivity Screening
To test whether the extracted compounds are biologically active (e.g., anticancer, antimicrobial).
Techniques:

a. In vitro Assays:
- Cytotoxicity assays (e.g., MTT, LDH)
- Antibacterial assays (e.g., MIC tests)
- Enzyme inhibition (e.g., protease, kinase)

b. Reporter Gene Assays: Using fluorescent or luminescent markers.
c. High-throughput Screening (HTS): Automates the testing of thousands of samples.



(Source:https://www.csescienceeditor.org/article/how-life-science-journals-can-be-champions-of-better-material-sharing-and-reporting/

Co-funded by the European Union

SustainaBlue
HEIs stands for Higher Education Institutions

Techniques Used in Marine Bioprospecting

6. Isolation and Structural Elucidation

Once a compound is active, it must be purified and identified.

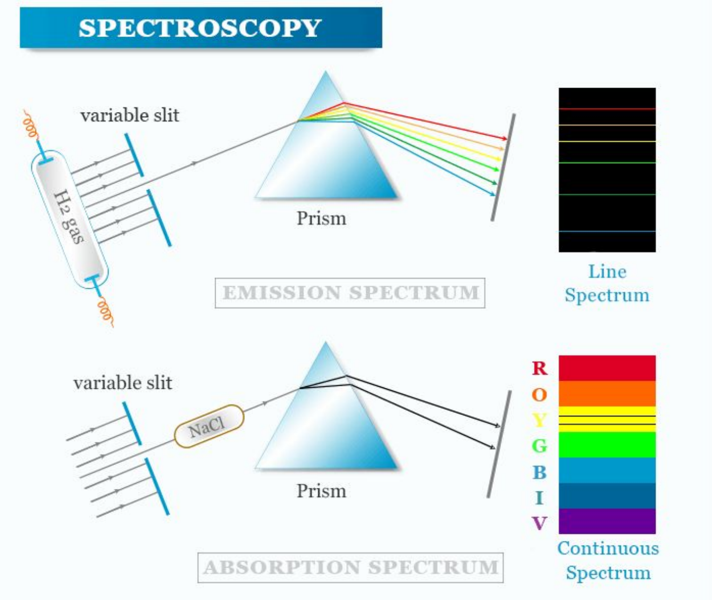
Techniques:

a. Chromatography:

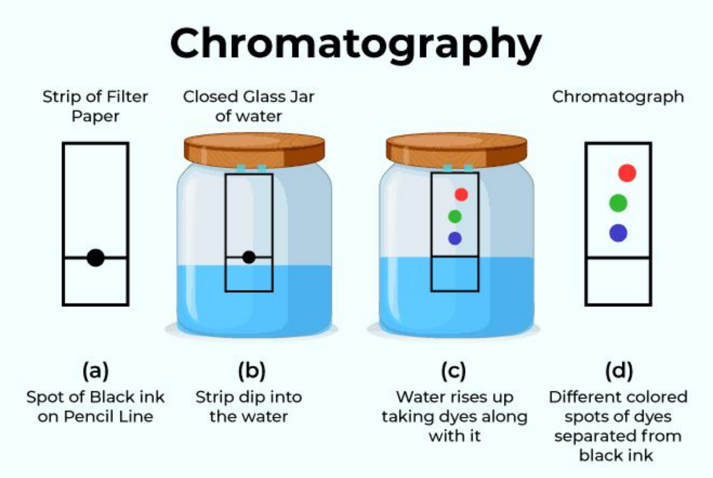
- Thin Layer Chromatography (TLC)
- High-Performance Liquid Chromatography (HPLC)
- Gas Chromatography-Mass Spectrometry (GC-MS)

b. Spectroscopy:

- Nuclear Magnetic Resonance (NMR)
- UV-Vis and IR spectroscopy
- Mass Spectrometry (MS)



(Source:https://www.priyamstudycentre.com/chemistry/spectroscopy)



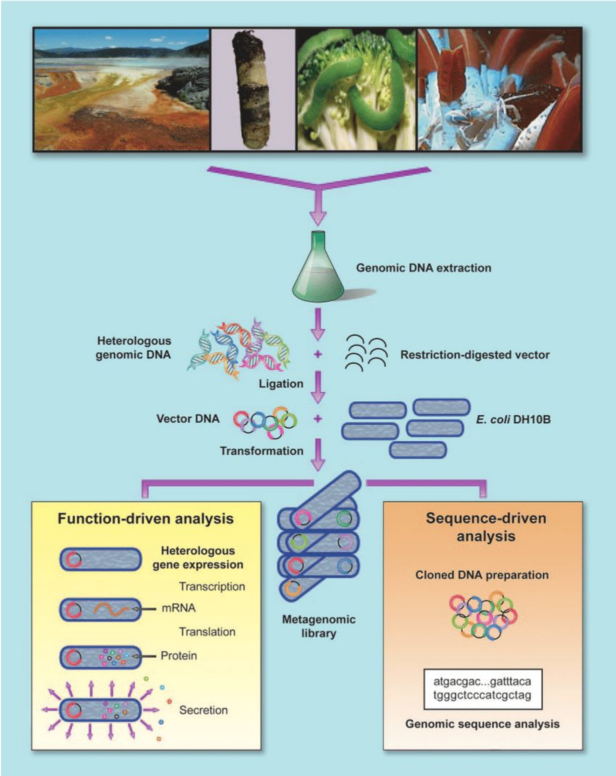
(Source:https://www.geeksforgeeks.org/chemistry/chromatography/)

7. Genomic and Synthetic Approaches

Used when organisms are unculturable or compounds are scarce.

Techniques:

- Metagenomic Libraries: Clone environmental DNA into hosts to produce compounds.
- Genome Mining: Search for biosynthetic gene clusters (e.g., polyketide synthases).
- Synthetic Biology: Insert genes into model organisms (like *E. coli*) to produce marine compounds.



(Source:https://www.bio.davidson.edu/courses/genomics/2014/Cambronero/Metagenomics.html)

Co-funded by the European Union

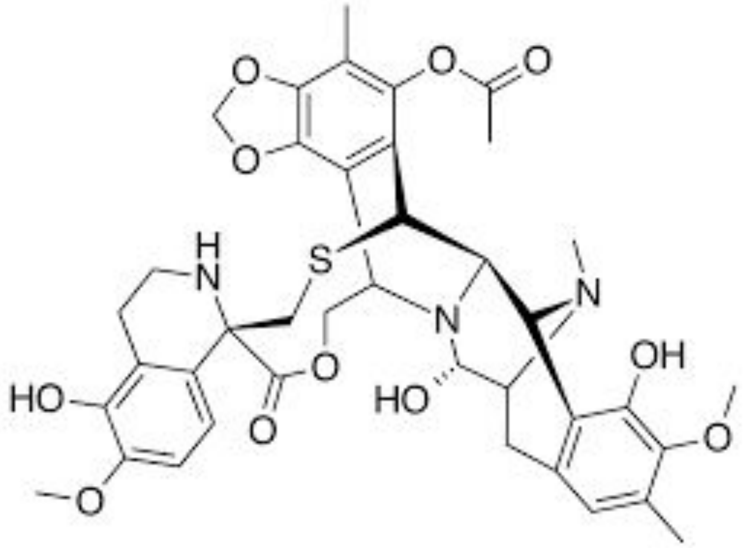
Bioactive Compounds from the Sea

- **Trabectedin** (van Kesteren *et al.*, 2003)

Trabectedin, an anticancer drug, is a marine-derived compound initially isolated from the Caribbean tunicate *Ecteinascidia turbinata*.

It's a semi-synthetic molecule that acts as a DNA-binding agent, specifically targeting the minor groove of DNA.
This interaction with DNA leads to a distortion of the double helix structure, inducing DNA damage and ultimately promoting cancer cell death (apoptosis).


Ecteinascidia turbinata.



(Source:van Kesteren *et al.*, 2003)

Co-funded by the European Union

SustainaBlue
HEIs stands for Higher Education Institutions

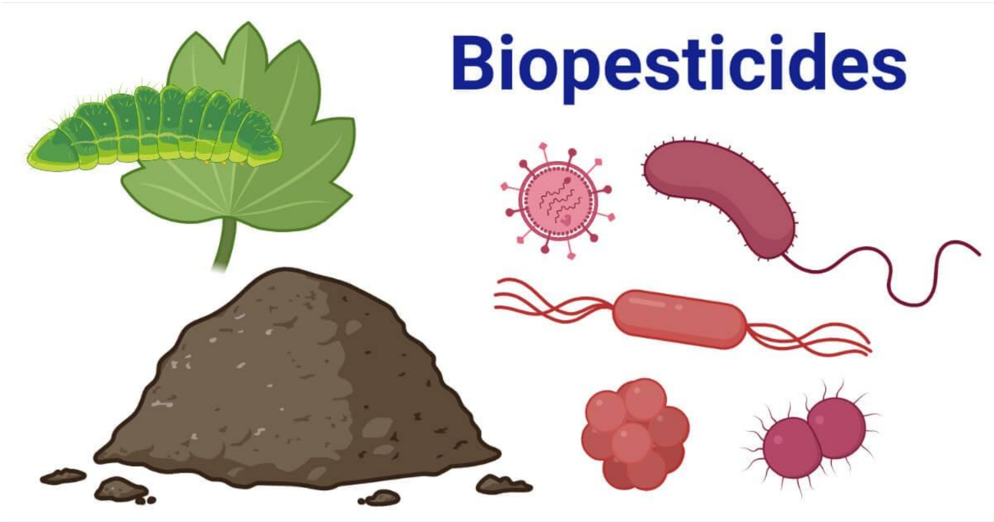
Applications in Industry

- ❑ Medicine: cancer, infections

- ❑ Nutraceuticals: omega-3 algae

- ❑ Cosmetics: UV protection

- ❑ Agriculture: biopesticides



Co-funded by
the European Union

SustainaBlue
HEIs stands for Higher Education Institutions

Applications in Medicine: Cancer, Infections

1. Cancer Therapy

Several marine-derived compounds have been developed into **anticancer drugs**:

a) Trabectedin (Yondelis®) (van Kesteren *et al.*, 2003)

Source: *Ecteinascidia turbinata* (sea squirt)
Action: Binds to DNA, disrupting the cell cycle of cancer cells.
Use: Approved for **soft tissue sarcoma** and **ovarian cancer**.
Commercialized by: PharmaMar

b) Eribulin (Halaven®) (Menis, *et al.*, 2011)

Source: Synthetic analog of **halichondrin B** from a marine sponge (*Halichondria okadai*)
Action: Inhibits microtubule dynamics in cancer cells
Use: **Metastatic breast cancer** and **liposarcoma**
Commercialized by: Eisai Co., Japan

c) Bryostatin 1 (Kowalczyk *et al.*, 2025)

Source: *Bugula neritina* (bryozoan)
Use: Investigated in **leukemia**, **lymphoma**, and as an immune modulator
Mechanism: Modulates protein kinase C (PKC) activity


bryostatin 1

Co-funded by
the European Union

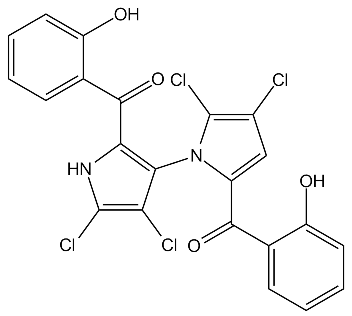
SustainaBlue
HEIs stands for Higher Education Institutions

Applications in Medicine: Cancer, Infections

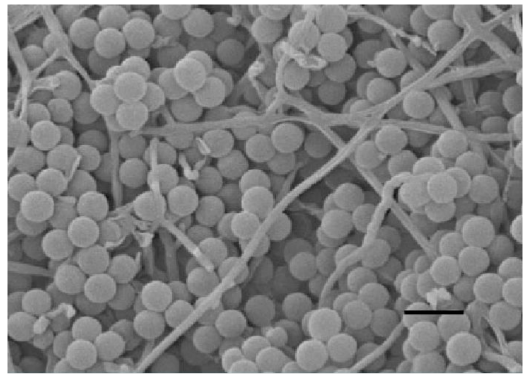
1. Infection

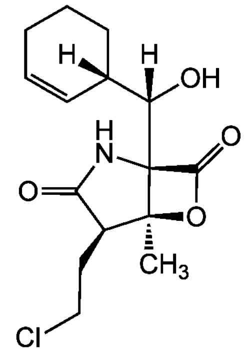
Antimicrobial & Antiviral Agents

a) Marinopyrrole A (Hughes *et al.*, 2010)
Source: *Streptomyces* spp. from marine sediments
Use: Broad-spectrum **antibacterial** activity including MRSA

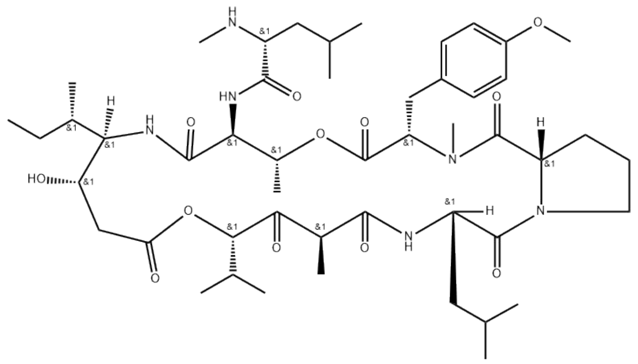


b) Salinosporamide A (Marizomib) (Feling *et al.*, 2003)
Source: *Salinispora tropica*, a marine actinomycete
Action: Proteasome inhibitor
Status: In clinical trials for **multiple myeloma** and **glioblastoma**





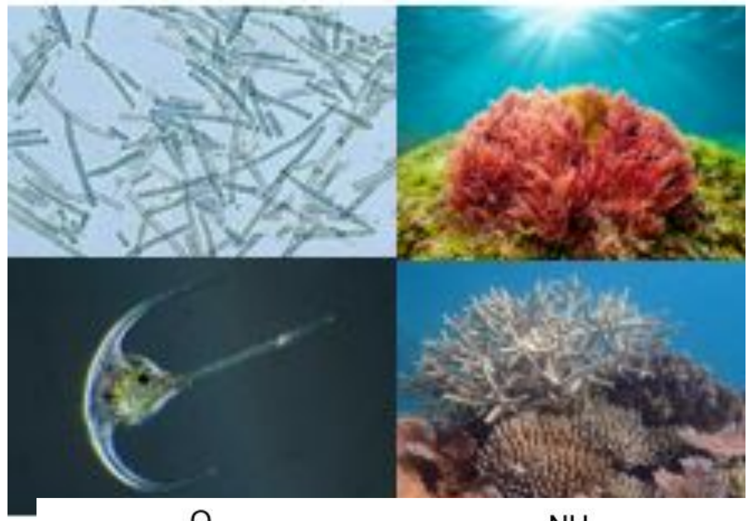
c) Didemnins (Rinehart *et al.*, 1981)
Source: *Trididemnum solidum* (sea squirt)
Use: Antiviral and anticancer (e.g., plitidepsin shows promise against **SARS-CoV-2** and **multiple myeloma**)
Commercialized by: PharmaMar

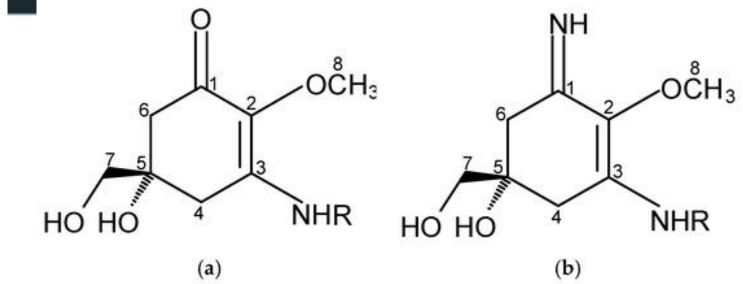


Co-funded by
the European Union

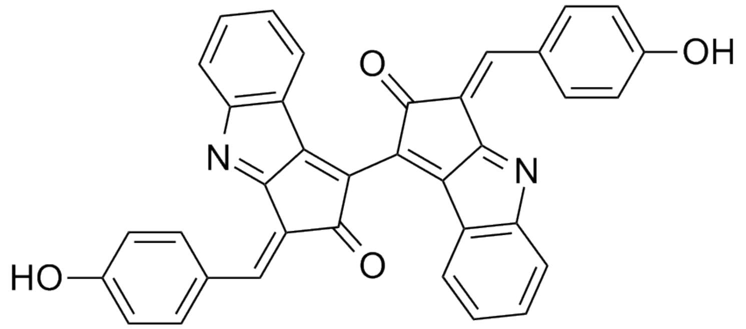
Applications in Cosmetics: UV Protection

A. Mycosporine-like Amino Acids (MAAs) (Singh *et al.*, 2021)
Sources: Cyanobacteria, red algae, dinoflagellates, corals.
Function: Act as natural sunscreens absorbing UV-A and UV-B radiation (310–360 nm).
Properties: Photostable (don't degrade easily in sunlight), Water-soluble, Antioxidant activity
Applications: Used in natural sunscreen formulations, Incorporated in anti-aging and moisturizing products.





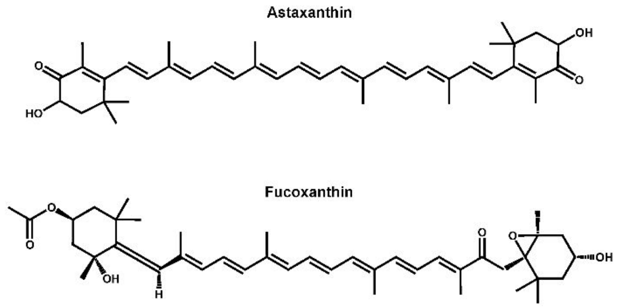
B. Scytonemin (Ručová *et al.*, 2023)
Source: Cyanobacteria (e.g., Scytonema species).
Function: Strong UV-A absorber.
Properties: Lipid-soluble, Anti-inflammatory and antioxidant
Application: Potential for anti-photoaging cosmetics



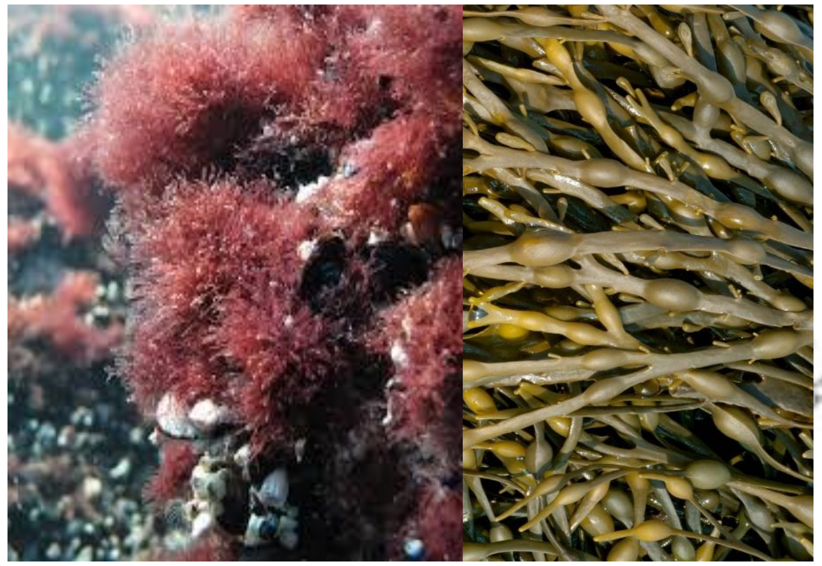
Co-funded by
the European Union

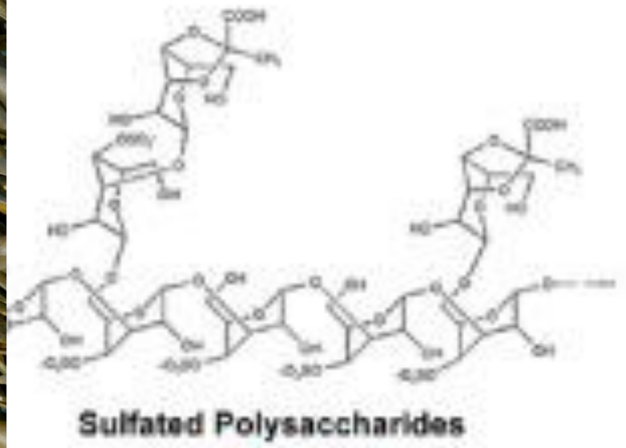
Applications in Cosmetics: UV Protection

C. Marine Carotenoids (Shah *et al.*, 2025)
Examples: Astaxanthin, fucoxanthin
Sources: Microalgae, seaweeds, crustaceans
Function: Antioxidants that protect against UV-induced oxidative stress
Applications: Oral and topical formulations, Anti-wrinkle, skin-brightening, and anti-inflammatory effects



D. Polysaccharides from Algae (Li *et al.*, 2024)
Example: Sulfated polysaccharides
Source: Brown and red algae
Function: Hydration and skin barrier protection; some also show UV filtering capability.
Application: Enhances skin protection and is often used with other active ingredients.





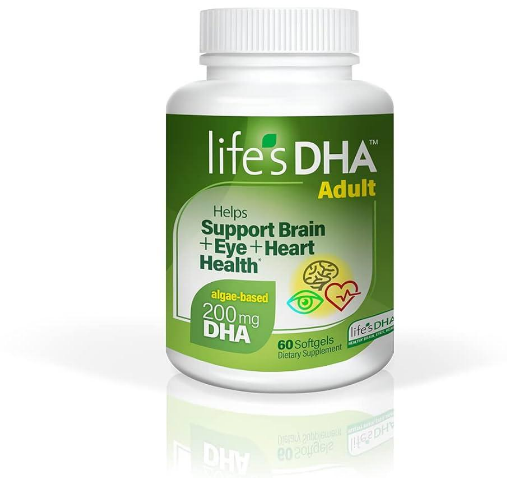
Applications in Cosmetics: UV Protection

Omega-3 algae (Parrish, 2024)
Marine bioprospecting has led to the discovery of numerous bioactive compounds, with omega-3 fatty acids being one of the most commercially successful nutraceuticals. These essential fatty acids, primarily eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), are derived from marine sources and play a crucial role in human health.

Sources:
Microalgae (Sustainable Alternative)

Schizochytrium sp. (high DHA content).
Crypthecodinium cohnii (used in vegan omega-3 supplements).
Phaeodactylum tricornutum (contains EPA).

Commercial Use:
Algal oil supplements
(e.g., Life’s DHA® by DSM, Neuromins® by Martek).



Applications in Nutraceuticals

Examples of Products & Brands

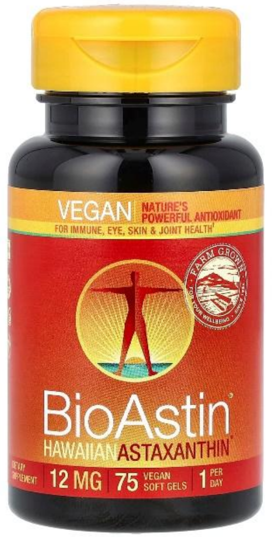
a) Helioguard® 365:
Contains MAAs derived from red algae (Porphyra umbilicalis); used as a natural UV-A filter in cosmetic creams.

(Schimd *et al.*, n.d.)

b) Blue Light Protection by Algaktiv®:
Uses MAAs to protect against blue light and UV.

(Algaktiv, 2024)

c) Bioastin®:
A supplement and topical ingredient rich in astaxanthin, used in anti-aging and sun-protective skincare.



(Ambati *et al.*, 2014)

Co-funded by the European Union

Applications in Agriculture: Biopesticide

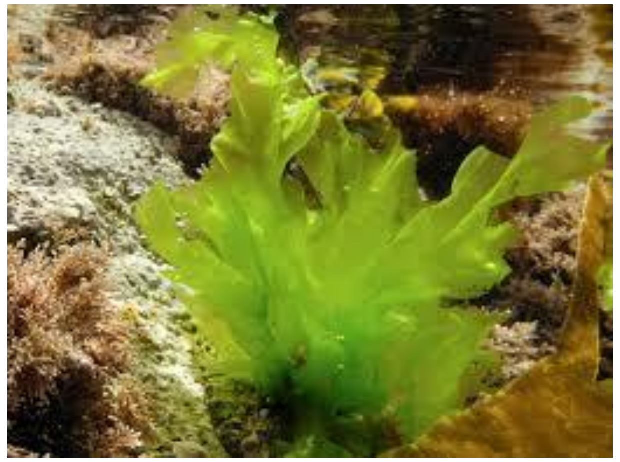
Seaweeds (Macroalgae) (Ganesh *et al.*, 2024)

Brown, green, and red seaweeds contain compounds like fucoidans, phlorotannins, polyphenols, peptides and polysaccharides with pesticidal effects (herbicidal, fungicidal, insecticidal, nematicidal, repellents).

Examples:

- *Ascophyllum nodosum* extracts promote resistance to fungal and bacterial pathogens in crops like tomato and maize, by priming plant defense enzymes.
- *Gracilaria, Ulva lactuca, Sargassum* species exhibit insecticidal, fungicidal, nematicidal, repellent effects through various extraction methods.

Ascophyllum nodosum



Ulva lactuca

Gracilaria

Sargassum

Co-funded by the European Union

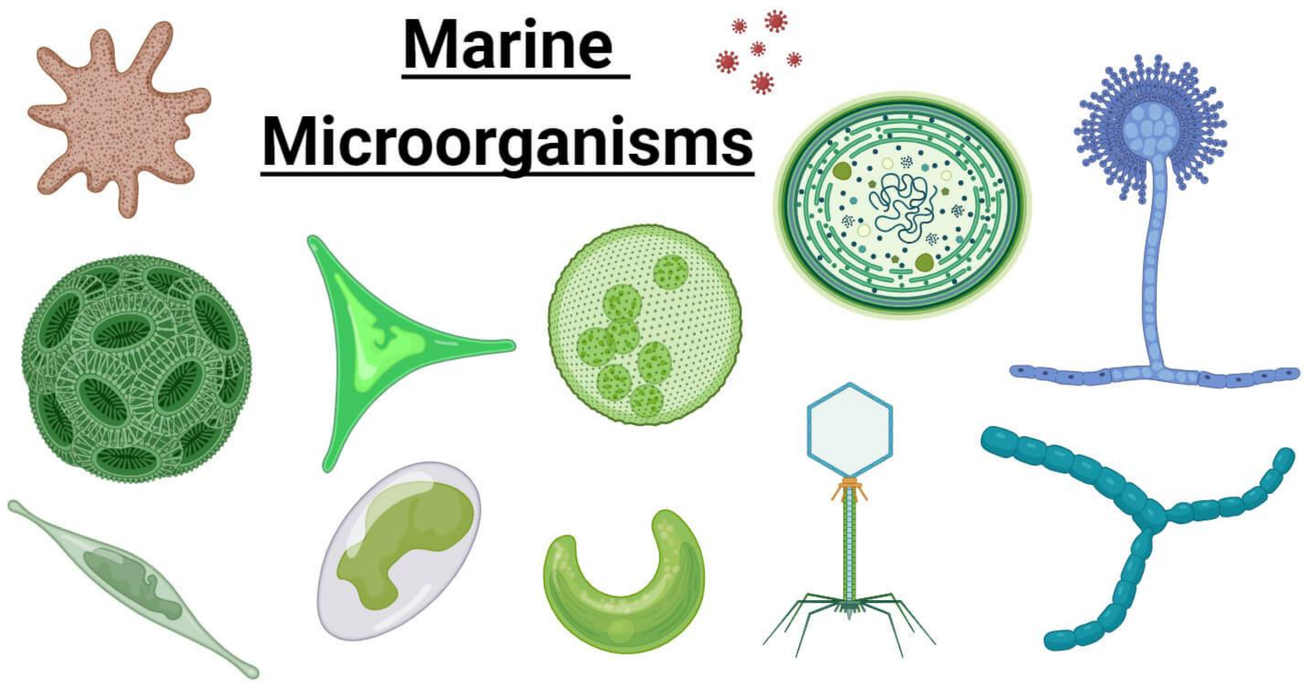
Applications in Agriculture: Biopesticide

SustainaBlue
HEIs stands for Higher Education Institutions

Marine Microorganisms & Fungi (Rodrigues et al., 2022)

Marine fungi and actinomycetes produce novel alkaloids, peptides, polyketides with potent anti-phytopathogenic and insecticidal activities.

For instance, certain marine fungi produced compounds active against plant pathogens in lab screens known **marine-derived pesticides** include nereistoxin analogues used regionally, and newly discovered coral- and sponge-derived alkaloids/insecticides like **manzamine A, hydroxycolorenone, pyridoacridines** with specific activity against agricultural pests.



Co-funded by the European Union

Ethical, Legal, Environmental Issues

- Nagoya Protocol
- Access & Benefit-Sharing (ABS)
- Biopiracy
- Sustainable sampling practices

Ethical, Legal, Environmental Issues

Nagoya Protocol

The Nagoya Protocol is **an international agreement under the Convention on Biological Diversity (CBD)** that aims to ensure the fair and equitable sharing of benefits arising from the utilization of genetic resources and traditional knowledge associated with them.

It establishes a legal framework for access to genetic resources and associated traditional knowledge, promoting transparency and legal certainty for both providers and users.

(Secretariat of the Convention on Biological Diversity, 2011)

Co-funded by the European Union

Ethical, Legal, Environmental Issues

❑ Access & Benefit-Sharing (ABS)

Marine bioprospecting, the exploration of marine genetic resources for valuable compounds, necessitates an Access and Benefit-Sharing (ABS) framework to ensure fair and equitable distribution of benefits derived from these resources. This framework addresses the challenge of accessing marine genetic resources, particularly in areas beyond national jurisdiction, and aims to fairly distribute the profits from commercialization of products derived from these resources.

Key Aspects of Marine Bioprospecting ABS:

- **Access:**

Determining who can access marine genetic resources and under what conditions.

- **Benefit Sharing:**

Establishing mechanisms for sharing the benefits derived from the utilization of marine genetic resources.

- **International Law:**

The UN Convention on the Law of the Sea (UNCLOS) and the Nagoya Protocol, which governs access to and benefit-sharing of genetic resources.

- **Monitoring and Compliance:**

Implementing effective measures to monitor the utilization of marine genetic resources and ensure compliance with ABS agreements.

SustainaBlue
HEIs stands for Higher Education Institutions
Co-funded by the European Union

Ethical, Legal, Environmental Issues

Biopiracy

Biopiracy in marine bioprospecting refers to the unauthorized or unethical appropriation and commercialization of genetic resources and traditional knowledge from the oceans, often without fair compensation or benefit-sharing with the communities or countries where the resources originated.

Key aspects of biopiracy in marine bioprospecting:

- **Unauthorized Access:**
Accessing marine genetic resources (like microorganisms, plants, and animals) without proper authorization from the relevant authorities or communities.
- **Commercialization without Benefit-Sharing:**
Commercialized without fairly sharing the benefits with the communities or countries that provided the resources.
- **Exploitation of Traditional Knowledge:**
Exploited without proper recognition or compensation to the indigenous communities who possess this knowledge.
- **Impact on Biodiversity and Communities:**
Depletion of marine resources, negatively impact biodiversity, and deprive local communities of potential economic benefits and cultural heritage.

Co-funded by the European Union

SustainaBlue
HEIs stands for Higher Education Institutions

Summary

- Marine bioprospecting = future of biotechnology
- Potential for health, food, and environmental innovation
- Needs science, ethics, policy

Co-funded by the European Union

Bibliography

SustainaBlue
HEIs stands for Higher Education Institutions

Davidson, S.K., Allen, S.W., Lim, G.E., Anderson, C.M. and Haygood, M.G. (2001). Evidence for the Biosynthesis of Bryostatins by the Bacterial Symbiont 'Candidatus Endobugula sertula' of the BryozoanBugula neritina. *Applied and Environmental Microbiology*, 67(10), pp.4531–4537. doi:https://doi.org/10.1128/aem.67.10.4531-4537.2001.

Flemsæter, F. (2020). Regulating marine bioprospecting. Exploring the establishment of new regulatory regimes in the blue bioeconomy. *Ocean & Coastal Management*, 194, p.105207. doi:https://doi.org/10.1016/j.ocecoaman.2020.105207.

Ganesh, C., Pullagura, S., Nagendra, Urkude, A. and Yadav, M. (2024). Marine Bioprospecting: Novel Use of Ocean Resources. *Vigyan Varta*, [online] 5(10). Available at: https://www.vigyanvarta.in/adminpanel/upload_doc/VV_1024_22-C.pdf.

Hosseini, H., Al-Jabri, H.M., Moheimani, N.R., Siddiqui, S.A. and Saadaoui, I. (2022). Marine microbial bioprospecting: Exploitation of marine biodiversity towards biotechnological applications—a review. *Journal of Basic Microbiology*. doi:https://doi.org/10.1002/jobm.202100504.

Rodrigues, C.J.C. and de Carvalho, C.C.C.R. (2022). Marine Bioprospecting, Biocatalysis and Process Development. *Microorganisms*, 10(10), p.1965. doi:https://doi.org/10.3390/microorganisms10101965.

Shetty, N. and Gupta, S. (2014). Eribulin drug review. *South Asian Journal of Cancer*, [online] 3(1), pp.57–59. doi:https://doi.org/10.4103/2278-330X.126527.

Shukla, P.S., Mantin, E.G., Adil, M., Bajpai, S., Critchley, A.T. and Prithiviraj, B. (2019). Ascophyllum nodosum-Based Biostimulants: Sustainable Applications in Agriculture for the Stimulation of Plant Growth, Stress Tolerance, and Disease Management. *Frontiers in Plant Science*, 10. doi:https://doi.org/10.3389/fpls.2019.00655.

Singh, A., Čížková, M., Bišová, K. and Vítová, M. (2021). Exploring Mycosporine-Like Amino Acids (MAAs) as Safe and Natural Protective Agents against UV-Induced Skin Damage. *Antioxidants*, 10(5), p.683. doi:https://doi.org/10.3390/antiox10050683.

van Kesteren, Ch., de Vooght, M.M.M., López-Lázaro, L., Mathôt, R.A.A., Schellens, J.H.M., Jimeno, J.M. and Beijnen, J.H. (2003). Yondelis® (trabectedin, ET-743): the development of an anticancer agent of marine origin. *Anti-Cancer Drugs*, 14(7), pp.487–502. doi:https://doi.org/10.1097/00001813-200308000-00001.

Co-funded by
the European Union

Bibliography

SustainaBlue
HEIs stands for Higher Education Institutions

Menis, J., & Twelves, C. (2011). Eribulin (Halaven): A new, effective treatment for women with heavily pretreated metastatic breast cancer. Breast Cancer: Targets and Therapy, 3, 101–111. https://doi.org/10.2147/BCTT.S21741 \

Skirycz, A., Kierszniowska, S., Méret, M., Willmitzer, L., & Tzotzos, G. (2016). Medicinal bioprospecting of the Amazon rainforest: A modern Eldorado? Trends in Biotechnology, 34(10), 781–790. https://doi.org/10.1016/j.tibtech.2016.03.006

Singh, R., Chauhan, N., & Kuddus, M. (2021). Exploring the therapeutic potential of marine-derived bioactive compounds against COVID-19. Environmental Science and Pollution Research, 28, 52798–52809. https://doi.org/10.1007/s11356-021-16104-6

Chang, Y., Hou, F., Pan, Z., Huang, Z., Han, N., Bin, L., Deng, H., Li, Z., Ding, L., Gao, H., Zhi, F., Yang, R., & Bi, Y. (2019). Optimization of culturomics strategy in human fecal samples. Frontiers in Microbiology, 10, 2891. https://doi.org/10.3389/fmicb.2019.02891

Erkey, C. (2009). Supercritical Fluids and Their Applications. In M. A. McHugh & V. J. Krukonis (Eds.), Supercritical Fluid Science and Technology (pp. 135–176). Elsevier. https://doi.org/10.1016/B978-0-08-045329-3.00006-8

Kowalczyk, T., Gawel, D., & Gawel, K. (2025). Anticancer activity of the marine-derived compound Bryostatin 1. International Journal of Molecular Sciences, 26(16), 7765. https://doi.org/10.3390/ijms26167765

Hughes, C. C., MacMillan, J. B., Gaudêncio, S. P., Jensen, P. R., & Fenical, W. (2010). Marinopyrrole A: Antibiotic activity and synthesis. Organic Letters, 12(18), 4228–4231. https://doi.org/10.1021/ol101801r

Feling, R. H., Buchanan, G. O., Mincer, T. J., Kauffman, C. A., Jensen, P. R., & Fenical, W. (2003). Salinosporamide A: A highly cytotoxic proteasome inhibitor from a novel marine bacterium. Angewandte Chemie International Edition, 42(3), 355–357. https://doi.org/10.1002/anie.200390119

Rinehart, K. L., Holt, T. G., Fregeau, N. L., Stroh, J. G., Keifer, P. A., Sun, F., & Li, L. H. (1981). Didemnins: Antiviral and antitumor depsipeptides from a Caribbean tunicate. Journal of the American Chemical Society, 103(7), 1857–1859. https://doi.org/10.1021/ja00400a056

Co-funded by
the European Union

Bibliography

SustainaBlue
HEIs stands for Higher Education Institutions

Ručová, D., Vilková, M., Sovová, S., Vargová, Z., Kostecká, Z., Frenák, R., Routray, D., & Bačkor, M. (2023). Photoprotective and antioxidant properties of scytonemin isolated from Antarctic cyanobacterium Nostoc commune and its potential as sunscreen ingredient. Journal of Applied Phycology, 35, 2839–2850. https://doi.org/10.1007/s10811-023-03109-6

Shah, F. I., Imran, H., Akram, F., Khalid, T., & Shehzadi, S. (2025). Marine carotenoids: Unlocking advanced antioxidant mechanisms and therapeutic applications for oxidative stress. Molecular Biotechnology. https://doi.org/10.1007/s12033-025-01420-w

Li, C., Wang, H., Zhu, B., Yao, Z., & Ning, L. (2024). Polysaccharides and oligosaccharides originated from green algae: Structure, extraction, purification, activity and applications. Bioresources and Bioprocessing, 11, Article 85. https://doi.org/10.1186/s40643-024-00800-5

Parrish, C. C. (2024). Thraustochytrids and algae as sustainable sources of long-chain omega-3 fatty acids for aquafeeds. Sustainability, 16(21), 9142. https://doi.org/10.3390/su16219142

Secretariat of the Convention on Biological Diversity. (2011). Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity: Text and annex. United Nations. https://www.cbd.int/abs/text

Ambati, R. R., Phang, S.-M., Ravi, S., & Aswathanarayana, R. G. (2014). Astaxanthin: Sources, extraction, stability, biological activities and its commercial applications—A review. Marine Drugs, 12(1), 128–152. https://doi.org/10.3390/md12010128

Schmid, D., Schürch, C., & Zülli, F. (n.d.). Helioguard® 365: Mycosporine-like amino acids from red algae protect against premature skin aging. Mibelle Biochemistry. Retrieved from: https://www.personalcaremagazine.com/story/44274/algaktiv-reveals-retinart-clinical-study-findings

Algaktiv. (2024). Algaktiv RetinART: Clinical study findings on marine-based retinol alternative. Personal Care Magazine. Retrieved from: Algaktiv reveals RetinArt clinical study findings

Co-funded by the European Union

SustainaBlue

HEIs stands for Higher Education Institutions

THANK YOU

sustainablue@sci.ui.ac.id

SustainaBlue HEIs in Malaysia and Indonesia

Co-funded by the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Project: 101129136 — SustainaBlue — ERASMUS-EDU-2023-CBHE