6. Marine & Space Biotechnology – S & T

Futuristic marine and space biotechnology India is focusing on futuristic marine and space biotechnology to harness underexplored environments like deep oceans and microgravity for sustainable biomanufacturing and strategic autonomy. However, despite initiatives like the Deep Ocean Mission and BioE3, challenges such as fragmented R&D, low domestic production of marine biomass, and limited private participation hinder full realization of this potential.

Introduction

Futuristic space and marine biotechnology research focuses on harnessing underexplored environments—specifically the deep oceans and outer space—to develop novel biological knowledge, advanced materials, and sustainable manufacturing processes.

1. Understanding the Domains- Marine vs. Space Biotechnology

Feature	Marine Biotechnology	Space Biotechnology
Focus Area	Study of marine microorganisms, algae, and other aquatic life forms.	Study of microbes, plants, and human biological systems under microgravity and radiation.
Key Discoveries	Bioactive compounds, enzymes, biomaterials, food ingredients, and biostimulants.	Microbial biomanufacturing for food and materials; insights into astronaut microbiomes.
Adaptation Mechanism	Organisms evolve to survive high pressure, salinity, low light, and nutrient-poor conditions.	Systems adapt to extreme environments to support life-support regeneration and health interventions.
Applications	Industrial use, climate-resilient crops, and sustainable resource management.	Closed-loop life-support systems, drug discovery, and regenerative medicine for long-duration missions.

2. Global Progress and Leadership

European Union (EU)

Funding- Supports large-scale programs on marine bioprospecting.
Focus- Algae-based biomaterials and bioactive compounds.
Infrastructure- Shared resources like the European Marine Biological Resource Centre support these initiatives.
Space- The European Space Agency (ESA) conducts experiments on plant growth and biomaterials in microgravity.

China

Marine Strategy- Rapid expansion of seaweed aquaculture and marine bioprocessing.
Integration- Combines deep-sea exploration with industrial applications in food, pharmaceuticals, and biomaterials.
Space Strategy- The Tiangong space programme is active in experimenting with microbiomes and biomaterials generation.

United States

Space Leadership- Leads through NASA and the International Space Station (ISS).
Research Areas- Microbial behavior, protein crystallization, stem cells, and closed-loop life-support systems.
Marine- Supports marine biotech initiatives alongside other resource-rich nations like Australia.

Japan

Space- JAXA (Japan Aerospace Exploration Agency) is a key player in microgravity experiments involving plant growth and biological systems.

3. Importance for India

Strategic Advantages

Marine Assets- India possesses an 11,000-km coastline and a 2-million-sq-km Exclusive Economic Zone (EEZ), offering immense access to marine biodiversity.

Bioeconomy- Strengthening these sectors can enhance India's bioeconomy and strategic autonomy.

Resource Security

Alternative Sources- Investing in marine biomanufacturing can unlock new sources of food, energy, chemicals, and biomaterials.

Sustainability- This eases the pressure on traditional land-based resources, freshwater, and agriculture.

Space Ambitions

Long-term Exploration- Space biotechnology is critical for enabling safe food production and human health management in extreme environments, positioning India as a leader in next-generation biomanufacturing.

4. Present Status of India

Marine Biotechnology Sector

Production Volume- Domestic production of marine biomass (e.g., seaweed) is modest, with an annual cultivated output of approximately 70,000 tonnes.

Import Dependency- India relies on imports for seaweed-derived components like agar, carrageenan, and alginates, which are crucial for food, pharmaceuticals, and cosmetics.

Key Initiatives

a. Blue Economy Agenda
b. Deep Ocean Mission
c. BioE3 Policy**-** Pushes for integrated marine biomanufacturing, linking cultivation to downstream applications.

Private Sector- A small number of private players are currently exploring pathways to scale marine biomass into high-value ingredients.

Space Biotechnology Sector

ISRO's Role- The microgravity biology programme is conducting experiments on microbes and algae.

Research Focus

a. Food production in space.
b. Life-support regeneration.

Astronaut Microbiomes- Gaining relevance as India prepares for longer-duration human spaceflight missions (Gaganyaan).

5. Challenges

Unexplored Frontiers- Both fields are relatively nascent; early movers will gain lasting strategic and technological advantages.

Slow Progress- The primary risk for India is slow and fragmented Research and Development (R&D).

Limited Participation- Private-sector involvement is currently limited due to the early stage of these technologies.

6. Suggestions and Way Forward

Leverage Ecology- India should utilise its rich and diverse marine ecology to emerge as a global leader in marine biotechnology.

Indigenous Solutions- Space biological technologies must be developed considering the genetic, nutritional, and health profiles of Indian populations, rather than relying on external solutions.

Dedicated Roadmap- A clear roadmap defining timelines and outcomes is essential to

a. Align investments.
b. Coordinate institutional efforts.
c. Channel resources effectively.

Source- https-//www.thehindu.com/sci-tech/science/what-is-futuristic-marine-and-space-biotechnology-explained/article70510981.ece