What is futuristic marine and space biotechnology? | Explained

How can India position itself as a leader in biomanufacturing?

Published – January 15, 2026 08:30 am IST

SHAMBHAVI NAIK

For representative purposes. | Photo Credit: Getty Images

The story so far: Futuristic space and marine biotechnology research focuses on using underexplored environments, such as the deep oceans and outer space, to develop new biological knowledge, materials, and manufacturing processes. Marine biotechnology involves studying microorganisms, algae, and other marine life to discover bioactive compounds, enzymes, biomaterials, food ingredients, and biostimulants. These organisms have evolved to survive high pressure, salinity, low light, and nutrient-poor conditions making them valuable for industrial and climate-resilient applications. Space biotechnology, meanwhile, studies how microbes, plants, and human biological systems behave under microgravity and radiation. This includes microbial biomanufacturing for food, materials, and life-support systems, as well as research on astronauts' microbiomes to develop health and probiotic interventions for long-duration missions.

Why does India need them?

India's long coastline of over 11,000 km and a vast Exclusive Economic Zone of over 2 million sq. km give it access to rich marine biodiversity and biomass. Yet its share of global marine outputs remains low, indicating significant untapped potential. Investing in marine biomanufacturing can unlock new sources of food, energy, chemicals, and biomaterials, while reducing pressure on land, freshwater, and agricultural systems. Similarly, space biotechnology is critical for India's long-term ambitions in space exploration, enabling safe food production, human health management, and biological manufacturing in extreme environments. Together, futuristic marine and space biotechnology can strengthen India's bioeconomy, enhance strategic autonomy, and position India as a leader in next-generation biomanufacturing.

Where does India stand today?

India's domestic production of marine biomass such as seaweed remains modest, with an annual cultivated output of around 70,000 tonnes. As a result, India continues to import seaweed-derived components such as agar, carrageenan, and alginates for use in food, pharmaceuticals, cosmetics, and medical applications. Targeted initiatives under the Blue Economy agenda, the Deep Ocean Mission, and, more recently, the BioE3 are pushing the sector toward integrated marine biomanufacturing, linking cultivation, extraction, and downstream applications. A small number of private players, such as Sea6 Energy and ClimaCrew, along with ICAR–Central Marine Fisheries Research Institute and state-led initiatives such as the Vibrant Gujarat Regional Conference, are exploring pathways to scale marine biomass into high-value ingredients, and bio-based products. In space biotechnology, ISRO's microgravity biology programme is conducting experiments on microbes, algae, and biological systems to study food production, life-support regeneration, and human health in space. Research on microbial behaviour and astronaut microbiomes is gaining relevance as India prepares for longer-duration human spaceflight missions. However, private-sector participation is limited as these technologies are still nascent.

What are other countries doing?

The European Union funds large-scale programmes on marine bioprospecting, algae-based biomaterials, and bioactive compounds, supported by shared research infrastructure such as the European Marine Biological Resource Centre. China has rapidly expanded seaweed aquaculture and marine bioprocessing integrating deep-sea exploration with industrial applications in food, pharmaceuticals, and biomaterials. Other countries with vast marine resources such as the United States and Australia also support marine biotech initiatives. In space biotechnology, the U.S. leads through NASA and the International Space Station, where research on microbial behaviour, protein crystallisation, stem cells, and closed-loop life-support systems informs drug discovery, regenerative medicine, and long-duration human missions. The European Space Agency, China's Tiangong programme, and Japan's JAXA conduct experiments on plant growth, microbiomes, and biomaterials generation in microgravity.

What next?

Marine and space biotechnology remain relatively unexplored frontiers, where early movers are likely to gain lasting strategic and technological advantages. India's rich and diverse marine ecology positions it well to emerge as a leader in marine biotechnology. Similarly, India's ambitions as a space-faring nation require the development of biological technologies that account for the genetic, nutritional, and health profiles of Indian populations, rather than relying solely on externally developed solutions. The primary risk lies in slow and fragmented progress in research and development. A dedicated roadmap that defines timelines and outcomes for marine and space biotechnology would help align investments, coordinate institutions, and channel resources more effectively.

Shambhavi Naik is chairperson, Takshashila Institution's Health & Life Sciences Policy.

Published – January 15, 2026 08:30 am IST