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BIOECONOMY

SYLLABUS:

GS 3 > Science and Technology >> Biotechnology

REFERENCE NEWS:

Union Minister of Science & Technology, Dr. Jitendra Singh called for a wider public understanding and inclusive participation in India's biotechnology mission, stating that every Indian is a stakeholder in the country's bioeconomy. Speaking here during the nationwide celebration of **World Bioproduct Day** – The **BioE3 Way,** the Minister reiterated the government's commitment to realizing **a $300 billion bioeconomy by 2030**.

World Bioproduct Day – The BioE3 Way

Vision for India's Bioeconomy

- India aims to achieve a **$300 billion bioeconomy by 2030**.
- Biotechnology seen as a **driver of the next industrial revolution**.

Inclusive and Decentralised Outreach

- Event featured a **synchronized national hourly dialogue series** – "Voices Across the Cities."
- Topics included **marine biomass, forest resources, agri-residue**, and **industrial valorisation**.
- Minister called it a **"hybrid outreach movement"**, involving **students, startups, and industries**.

Growth of India's Biotech Ecosystem

- Biotech startups have grown from **~50 to nearly 11,000** in the past decade.
- This leap is attributed to **policy support** and **institutional partnerships** (e.g., DBT, BIRAC, iBRIC+).

BioE3 Policy Highlights

- Focuses on **environmental sustainability, equity, and economic growth**.
- Aims to make India a global leader in **sustainable biomanufacturing**.
- Supports **pilot manufacturing, region-specific missions**, and **research-to-market pipeline**.

Biotechnology as a Source of Livelihood

- Emphasis on **green jobs** and **rural employment** through bioproducts like:
  - **Biodegradable packaging**
  - **Eco-friendly personal care products**
- Dr. Singh stated: *"Bioproducts are about livelihoods, not just labs."*

Education and Talent Development

- NEP 2020 termed a **"game-changer"**, allowing flexible pursuit of interest-based disciplines.
- Encouragement for **young scholars** to pursue biotech careers linked to aptitude, not just parental pressure.

Traditional Knowledge & Resource Utilisation

- India's rich **biodiversity and traditional systems** are underutilised.
- Emphasis on **valuing indigenous resources and knowledge**, unlike Western-centric past policies.

Need for Effective Science Communication

- Urged use of **social media, local languages, and relatable storytelling** to make biotech accessible.
- Suggested showcasing **success stories** to attract young talent.

Call for Broader Participation

- Future events to include voices from **farmers, fishermen, and local stakeholders**.
- Science must address **grassroots needs**, not remain confined to urban labs.

Biotechnology is not just for scientists—it is for **every citizen** and must be **linked to livelihoods and sustainability.**

INDIA'S BIOTECHNOLOGY SECTOR:

- The Indian biotechnology sector is valued at approximately **USD 130 billion in 2024**, and it is expected to reach around USD 150 billion by 2025, growing at a Compound Annual Growth Rate (CAGR) of 15-17%.
- India is among **the top 12 biotechnology destinations in the world** and **ranks third in the Asia-Pacific region.**
- It is recognised as a **sunrise sector** crucial in India's ambition to become USD 5trillion economy.
- With about 3% of global biotechnological market share, India is becoming a hub for delivering innovative and affordable healthcare solutions.
- India's biotechnology start-up ecosystem is vibrant, with over 5,000 biotech start-ups as of 2024. These start-ups are involved in innovative research in areas like gene editing, regenerative medicine, diagnostics, and synthetic biology.

The sector is broadly categorized into five segments:

Bio-Pharmaceuticals:

- Bio-pharmaceuticals is the largest segment, accounting for about **62% of the total biotechnology market in India.**
- India is a leading global supplier of vaccines, with its companies contributing significantly to global immunization programs.
- India's strong capabilities in **generic drug manufacturing** are also being extended to biopharmaceuticals.

Bio-Services:

- India is a hub for clinical research and contract research organizations (CROs), offering services like clinical trials, contract manufacturing, and drug development support.
- This segment is driven by **cost advantages and skilled manpower**.
- The increasing demand for outsourcing R&D and clinical trials to India from global pharmaceutical companies has bolstered this segment's growth.
- The country hosts the highest number of US FDA-approved plants outside the United States.

Bio-Agriculture:

- India is a major producer of genetically modified (GM) crops, particularly **Bt cotton,** which has been widely adopted and has significantly boosted agricultural productivity.
- India holds the 5th largest area of organic agricultural land globally.The Bio-Agriculture sector has the potential to nearly double its BioEconomy contribution from **USD 10.5 billion to USD 20 billion by 2025.**
- There is ongoing research and development in areas like crop protection, bio-fertilizers, and stress-resistant crops.

Bio-Industrial:

- **India's** bio-industrial sector includes the production of industrial enzymes, biofuels, and bioplastics.
- The government is promoting the use of **biofuels** to reduce reliance on fossil fuels and to address environmental concerns.
- The sector is also exploring **sustainable industrial processes** using biotechnology, such as **waste management and pollution control.**

Bioinformatics:

- **Data-Driven Biology** through Bioinformatics is a rapidly growing area, with applications in genomics, proteomics, and drug discovery.
- The integration of artificial intelligence (AI) and big data analytics is driving innovation in personalized medicine and precision agriculture.

- India is home to several bioinformatics companies and research institutions that are collaborating with global firms on cutting-edge projects.

SIGNIFICANCE OF BIOTECHNOLOGY TO INDIA:

- **Employment Opportunities**: The sector provides employment to millions of people, ranging from high-skilled jobs in research and development (R&D) to roles in manufacturing, quality control, and sales. The thriving start-up ecosystem in biotechnology also fosters entrepreneurship, creating more job opportunities.
  - Companies like Biocon, Serum Institute of India, and Bharat Biotech are not only leaders in the biotech sector but also major employers, driving economic growth through innovation and exports.
- **Vaccines and Biopharmaceuticals**: India is a leading global producer of vaccines, supplying over **60% of the world's vaccines**. The biotechnology sector has been instrumental in developing vaccines for diseases such as polio, hepatitis, and COVID-19, making healthcare accessible and affordable.
- **Affordable Medicine**: Through the production of **biosimilars and generic drugs**, the biotechnology sector has helped reduce the cost of medicines, making them accessible to a broader population both in India and globally.
  - The Serum Institute of India, the world's largest vaccine manufacturer, played a critical role in the global fight against COVID-19 by producing and distributing vaccines like Covishield at scale and at affordable prices.
- **Biofuels and Bioenergy**: The biotechnology sector is pivotal in developing alternative energy sources like biofuels, which help reduce reliance on fossil fuels and lower greenhouse gas emissions. This is crucial for India's energy security and climate change mitigation efforts.
  - The **National Policy on Biofuels** in India promotes the use of biofuels, such as ethanol blended with petrol, which is produced from biomass and agricultural residues.
- **Vaccine Diplomacy**: India's biotechnology sector has been at the forefront of global health initiatives, particularly in providing vaccines and medicines to developing countries at affordable prices. This has enhanced India's reputation as a responsible global leader.
  - During the COVID-19 pandemic, India supplied vaccines to over 90 countries under the "Vaccine Maitri" initiative, strengthening diplomatic ties and demonstrating India's commitment to global health.
- **Fortified Crops and Nutraceuticals**: The biotechnology sector has developed fortified crops and nutraceuticals that address micronutrient deficiencies, thereby improving nutritional security in India.

- The development of Golden Rice, a genetically modified rice variant rich in Vitamin A, aims to combat vitamin A deficiency

CHALLENGES FACED BY THE SUNRISE SECTOR:

- **Complex and Time-Consuming Approvals**: The approval process for GM crops in India is particularly challenging. Bt brinjal, a genetically modified eggplant, was approved by the Genetic Engineering Appraisal Committee (GEAC) in 2009 but was subsequently put on hold by the government due to public and political opposition. This uncertainty discourages investment in GM research and development.
- **IPR Protection**: The process of securing patents can be lengthy and costly, and there are concerns about the protection of biotech innovations, particularly in the context of biosimilars and new drugs.
  - The patent dispute between Novartis and the Indian government over the cancer drug Glivec highlighted the challenges in balancing IPR protection with the need for affordable medicines.
- **Limited Access to Capital**: Biotechnology is **a capital-intensive industry** requiring significant investment in research and development (R&D). Venture capitalists and investors are often hesitant to invest in biotech due to the high risks and long timelines associated with product development.
- **Infrastructure and Skill Gaps**: There is a need for more **world-class research** facilities, better access to advanced technologies, and greater collaboration between academia and industry.
  - The development of indigenous biotech products, such as biosimilars or novel therapeutics, often lags due to inadequate infrastructure and limited access to high-end research tools like CRISPR gene-editing technology.
- **Weak Industrial-academia Linkages**: While India has many prestigious research institutions like the Indian Institutes of Technology (IITs) and the Indian Institutes of Science Education and Research (IISERs), the transfer of technology from these institutions to industry is limited, which hinders the commercialization of innovations.
- **Public Perception and Activism**: Genetically modified organisms (GMOs) face significant public and political resistance in India. Concerns about the safety, environmental impact, and ethical considerations of GM crops have led to stringent regulations and bans
  - The moratorium on Bt brinjal and the long-standing delay in the approval of GM mustard reflect the challenges faced by biotech companies in navigating public sentiment and regulatory hurdles
- **Global Competitiveness**: Indian biotech companies face stiff competition from global players, particularly in markets like the United States and Europe. Gaining market access in these regions requires compliance with international quality standards, which can be costly and challenging for Indian firms.
  - **Indian** biosimilar companies, such as Biocon, have faced challenges in gaining regulatory approval in the U.S. and European markets due to stringent quality requirements and competition from established global giants.

- **Adoption of New Technologies**: While India has made progress in traditional biotech areas, there is inadequate focus on emerging fields such as synthetic biology, personalized medicine, and advanced gene therapies. This limits the sector's ability to innovate and stay at the forefront of global biotech trends.

BioE3 Policy: Aims to promote a **sustainable, circular, and innovation-driven bioeconomy**.

- Supports **Net Zero carbon goals** and **Lifestyle for Environment (LiFE)** initiatives.
- Forms part of India's "**Viksit Bharat" bio-vision**.
- Strengthen **R&D and entrepreneurship** in biotechnology.
- Accelerate **technology commercialization** via:
  - **Biomanufacturing hubs**
  - **Bio-AI hubs**
  - **Biofoundries**
- Expand **skilled workforce** and create **green jobs**.

Strategic Focus Areas

- **High-value bio-based chemicals, enzymes, and biopolymers**
- **Smart proteins** and **functional foods**
- **Precision biotherapeutics**
- **Climate-resilient agriculture**
- **Carbon capture and utilization**
- **Marine and space biotechnology research**

Significance

- Supports **green growth** and **circular economy** models.
- Helps address societal challenges like **climate change**, **food security**, and **healthcare**.
- Lays the foundation for a **resilient, future-ready biomanufacturing ecosystem** in India.

WAY FORWARD FOR A SUSTAINABLE AND BENEFICIARY REVOLUTION IN BIOTECHNOLOGY:

- **Streamline Regulatory Processes**: Simplifying and expediting the approval processes for biotechnology products, particularly in areas like genetically modified organisms (GMOs), biosimilars, and novel therapeutics, will encourage innovation and reduce delays.
  - The U.S. Food and Drug Administration (FDA) has established streamlined pathways for the approval of biosimilars, which has encouraged innovation and reduced the **time-to-market** for new products.
- **Promote Collaborative Research**: Strengthen the linkages between academic institutions and the biotech industry to facilitate the translation of research into commercial products. This can be achieved through public-private partnerships, joint research initiatives, and technology transfer offices. Establish and support more biotechnology incubation centres and innovation hubs within universities and research institutions to nurture start-ups and facilitate the commercialization of research.

    - The **Fraunhofer Institutes** in Germany are a model of industry-academia collaboration, focusing on applied research and close cooperation with industries
- **Increase Investment in R&D**: Boost funding for emerging fields such as synthetic biology, personalized medicine, and advanced gene therapies. This includes both government funding and incentives for private sector investment. Prioritize investment in cutting-edge technologies such as CRISPR gene editing, regenerative medicine, and bioinformatics to ensure that India remains at the forefront of global biotech innovation.
    - The UK's **Innovate UK** initiative provides grants and support for high-risk, high-reward research in biotechnology, fostering innovation and helping new technologies reach the market.
- **Develop World-Class Research Facilities**: Invest in building world-class research facilities and laboratories equipped with advanced technologies to support biotech research and development. Strengthen digital infrastructure to support bioinformatics and data-driven research, which is critical for genomics, proteomics, and precision medicine.
    - Singapore's **Biopolis** is a state-of-the-art research hub that houses top biotech companies and research institutions, providing a collaborative environment for innovation.
- **Skill Development Programs**: Focus on both technical skills and entrepreneurship to drive innovation. Encourage collaboration with international universities and research institutions to provide Indian students and researchers with exposure to global best practices and cutting-edge research.
    - Israel's strong focus on STEM education and continuous skill development in biotechnology has created a highly skilled workforce that drives innovation in the sector.
- **Sustainable Biotech Solutions**: Promote the use of green biotechnology in agriculture to reduce the environmental impact of farming. Establish clear ethical guidelines for research in areas like genetic modification, stem cell research, and synthetic biology.
    - The EU has implemented stringent ethical guidelines and sustainability standards for biotechnology research and development. India can develop similar frameworks to ensure that its biotech sector grows in a socially responsible and sustainable manner.
    - Brazil has implemented community engagement programs in its biotech initiatives, particularly in agriculture, to ensure that local communities are informed and involved in decision-making processes.
- **Quality Standards and Certifications**: Align Indian biotech products with international quality standards and certifications to enhance their acceptance in global markets. This will require investments in quality control, regulatory compliance, and adherence to Good Manufacturing Practices (GMP). Promote Indian biotech products in global markets

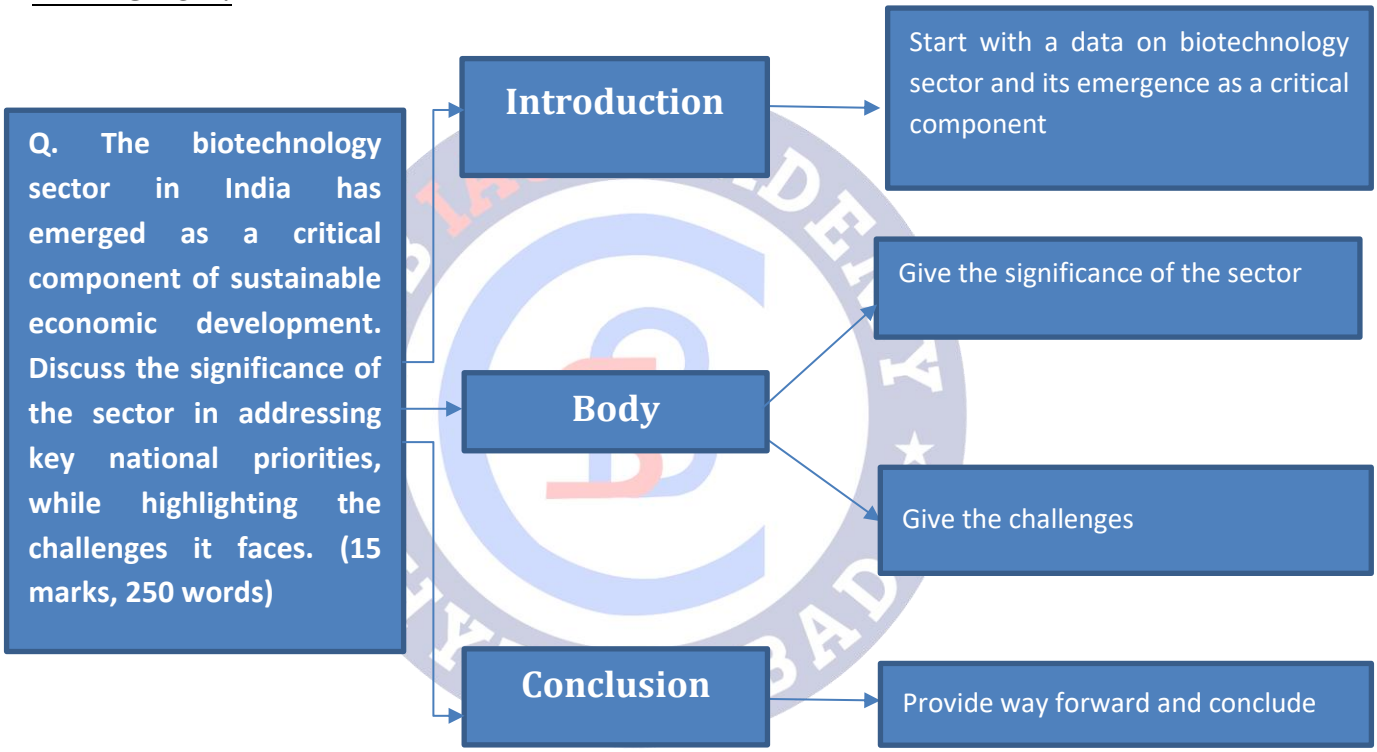
through trade agreements, export incentives, and participation in international biotech forums and exhibitions.

- South Korea has successfully integrated its biotech industry into the global market by focusing on quality standards, innovation, and strategic trade partnerships.

PRACTICE QUESTION:

Q. The biotechnology sector in India has emerged as a critical component of sustainable economic development. Discuss the significance of the sector in addressing key national priorities, while highlighting the challenges it faces. (15 marks, 250 words)

APPROACH:



MODEL ANSWER:

India's biotechnology sector, valued at **$130 billion in 2024**, is a key driver of sustainable development and innovation. With a vision to achieve a **$300 billion bioeconomy by 2030**, the sector is integral to India's efforts in ensuring health security, food safety, energy sustainability, and employment generation.

Significance of Biotechnology in India

- **Health & Vaccines:** India supplies **60% of global vaccines**, crucial during COVID-19 (e.g., **Vaccine Maitri** initiative).

- **Affordable Medicine:** Biosimilars and generic drugs have made critical therapies accessible to the masses.
- **Employment Generation:** The sector supports **millions of jobs**, especially through a vibrant start-up ecosystem with **11,000+ biotech startups**.
- **Agricultural Transformation:** Bio-agriculture, including **Bt cotton**, biofertilizers, and GM crops, improves yields and resilience.
- **Energy Security & Environment:** Biofuels like ethanol reduce dependency on fossil fuels and aid in **climate mitigation**.
- **Digital Biology:** Advances in **bioinformatics**, genomics, and **precision medicine** are transforming healthcare and research.
- **Global Leadership:** India's role in **vaccine diplomacy** and South-South cooperation boosts its global influence.

Challenges

- **Regulatory Hurdles:** Delays in GM crop approvals (e.g., **Bt Brinjal** and GM mustard) reflect policy inconsistency.
- **IPR and Investment Issues:** Weak patent protection and **limited venture capital** deter innovation.
- **Weak Industry-Academia Linkages:** Limits translation of research into products.
- **Infrastructure Gaps:** Lack of **world-class labs**, CRISPR tools, and digital infrastructure.
- **Public Perception:** GMOs face resistance due to ethical and environmental concerns.
- **Global Market Access:** Difficulties in meeting **international quality standards**.

Way Forward

- **Streamline Approvals:** Fast-track regulatory processes, inspired by **FDA biosimilar frameworks**.
- **Invest in R&D:** Prioritize emerging fields like **synthetic biology, AI-bio convergence**, and gene therapies.
- **Strengthen Collaboration:** Promote **industry–academia partnerships**, bioincubators, and joint ventures.
- **Develop Talent:** Expand biotech skill development and **international research exchange programs**.
- **Sustainable & Ethical Practices:** Promote **green biotech**, clear ethical frameworks, and **community participation**.
- **Global Integration:** Align with global **GMP and quality standards** to boost exports and competitiveness.

India's biotechnology sector has immense potential to drive **green growth, health equity, and global leadership**. With the right policy support, infrastructure, and public engagement, India can transform into a **biomanufacturing and bio-innovation powerhouse**, making the **BioE3 vision for Viksit Bharat** a reality.