Cu-Phen

Prelims – *General Science*

Mains – *General Studies-III (Science and Technology- developments and their applications and effects in everyday life. | Achievements of Indians in science & technology | Awareness in the fields of IT, Space, Computers, robotics, nanotechnology, biotechnology, and issues relating to intellectual property rights)*

Why in news?

Indian scientists at CSIR-Central Leather Research Institute (CLRI), Chennai have recently developed specialized Nano-sized particles called Cu-Phen that mimic the function of natural enzymes in our bodies.

- **Enzymes** – Are nature's catalysts, essential biological molecules that speed up chemical reactions vital for life.
- **Artificial enzymes** – Also known as nanozymes, which mimic the natural functions of enzymes using nanomaterials.
- These nanozymes hold immense potential in fields ranging from medicine to energy.

Challenge with First-Generation Nanozymes

- Earlier nanozymes often faced significant hurdles, limiting their practical application, especially within biological systems.
- A key challenge was their lack of specificity, often stemming from poorly defined "active sites" which are the parts responsible for the catalytic activity.
- This lack of precision could lead to:
    - Uncontrolled Electron Transfer
    - **Generation of Harmful Byproducts** – Leakage of electrons often resulted in the production of toxic Reactive Oxygen Species (ROS).
    - ROS can cause oxidative stress, damaging cells and contributing to various diseases and aging.
- These limitations posed risks, particularly for therapeutic applications, necessitating the development of next-generation nanozymes with better control and safety profiles.

Working Mechanism

- Cu-Phen is meticulously *self-assembled from copper ions (Cu^{2+})* coordinated with ligands (a molecule that binds to another) *derived from the amino acid phenylalanine*.
- It interacts precisely with ***cytochrome c***, a vital protein in the mitochondrial electron transport chain (the cell's primary energy-generating pathway).
- It binds to cytochrome c in a specific manner, similar to natural enzyme-substrate interactions.

- It facilitates the efficient transfer of electrons from cytochrome c.
- These *electrons are then used to reduce oxygen directly to water (H_2O)*, the safe end-product seen in natural cellular respiration.

Significance & Potential Applications

- **Well-Defined Active Site** – Unlike its predecessors, Cu-Phen features a *precisely engineered and defined active site*. This structural precision is key to its enhanced function.
- **Overcoming Limitations** – Its specific design enables *controlled electron transfer*, mimicking the efficiency of natural enzymes involved in cellular energy pathways.
- Crucially, this controlled process *avoids the generation of harmful ROS*.
- **Health & Therapeutics** – Its ability to function efficiently without producing harmful ROS makes it a prime candidate for *safer biomedical applications*.
- **Bioenergy** – Precise control over electron flow is fundamental to energy conversion.
- Cu-Phen could contribute to developing *more efficient biocatalysts for sustainable energy production* or understanding and manipulating cellular energy pathways.
- **Biotechnology & Environment** – Cu-Phen can guide the *development of advanced artificial enzymes for various biotechnological processes* and potentially environmental remediation tasks requiring specific catalytic activity.

Reference

PIB | Cu-Phen