Department of Biotechnology

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Nanotechnology

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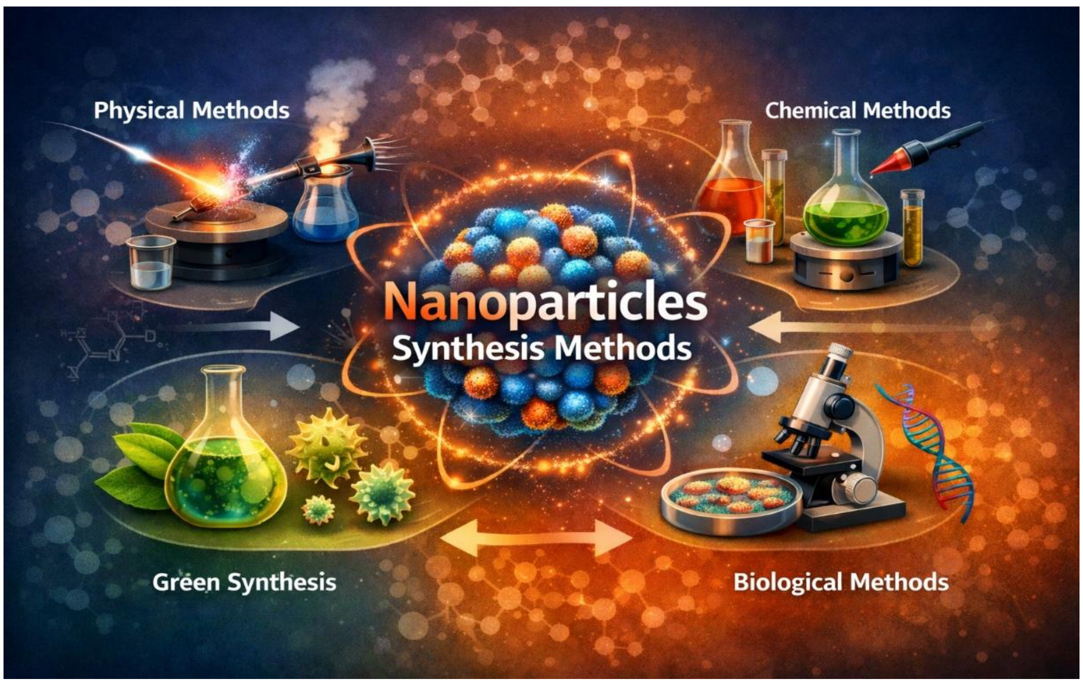

Nanoparticles synthesis methods

By

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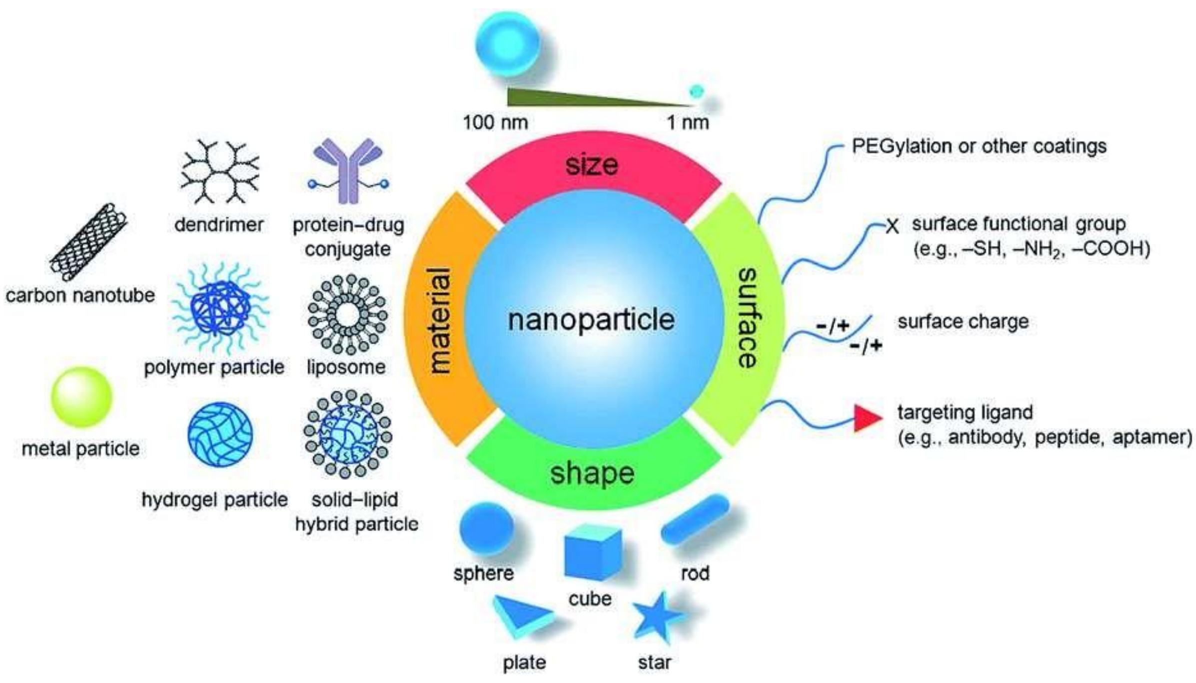
Nanotechnology deals with the synthesis of nanomaterials of various shapes and sizes and the study of their potential applications. However, the methods for manufacturing nanomaterials vary depending on the type of particles produced. In recent years, humans have increasingly turned to using nanomaterials in various industries due to their unique properties not found in larger-sized counterparts. Therefore, they have sought to synthesize nanomaterials artificially to obtain the desired particles, relying on methods that have evolved with the advancement of this field. The ability to control Precise over the physical and chemical properties of nanoparticles, such as shape, size, and surface chemistry, offers opportunities to tailor these nanostructures to the desired application. Therefore, three important properties are considered when fabricating nanomaterials, and these properties are used to classify them. Nanomaterials come in different types, and these are their properties:

1- **Shapes of nanoparticles**
2- **Sizes of nanoparticles**
3- **Surface structure of nanoparticles**

At the nanoscale, manufactured materials exist between 1 and 100 nanometers and offer uniquely useful functional forms. These nanoscale forms often possess distinct chemical and physical properties compared to their bulk counterparts, stemming from their large surface-to-volume ratio. The applications of nanoparticles vary depending on the size of the nanomaterials



themselves, enabling the application of nanotechnology in industry, agriculture, energy, environmental photocatalytic systems, materials engineering, sensors, and electronics, as well as in optics and pharmaceuticals within the medical field.

The size of nanoparticles dictates the type of technology used to manufacture them. Furthermore, the intended application plays a crucial role in determining the appropriate manufacturing technique. There is a wide variety of nanotechnology techniques available, offering varying degrees of quality, speed, and cost. These techniques can be broadly categorized into two main approaches: downward and upward.

Top-down Technology

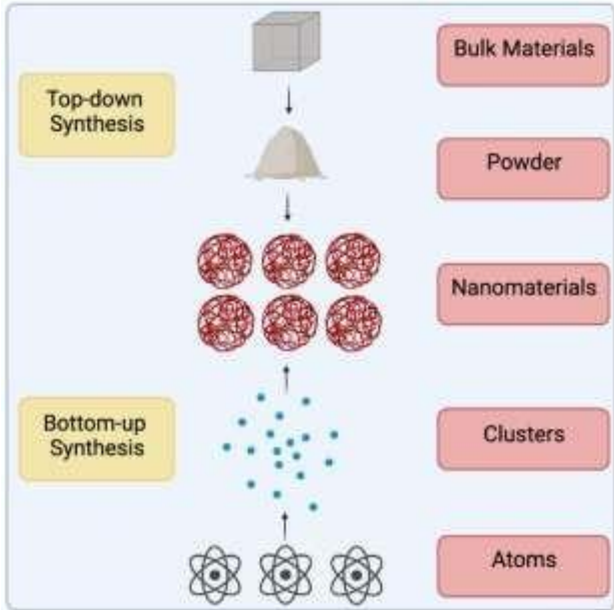
This method is metaphorically called the "fragmentation" or "slicing" method (the process of transforming materials of large sizes into smaller sizes while maintaining the same physical mass). It relies on the principle of removing atoms or molecules from the original, larger materials in a descending sequence. It begins with a significant amount of the material under study and gradually reduces it until it reaches the nanoscale. The use of thin films is a common method in this field for producing nanomaterials to the required dimensions.

These techniques have been used to create microelectronic components such as computer chips and other devices.

Bottom-up Technology

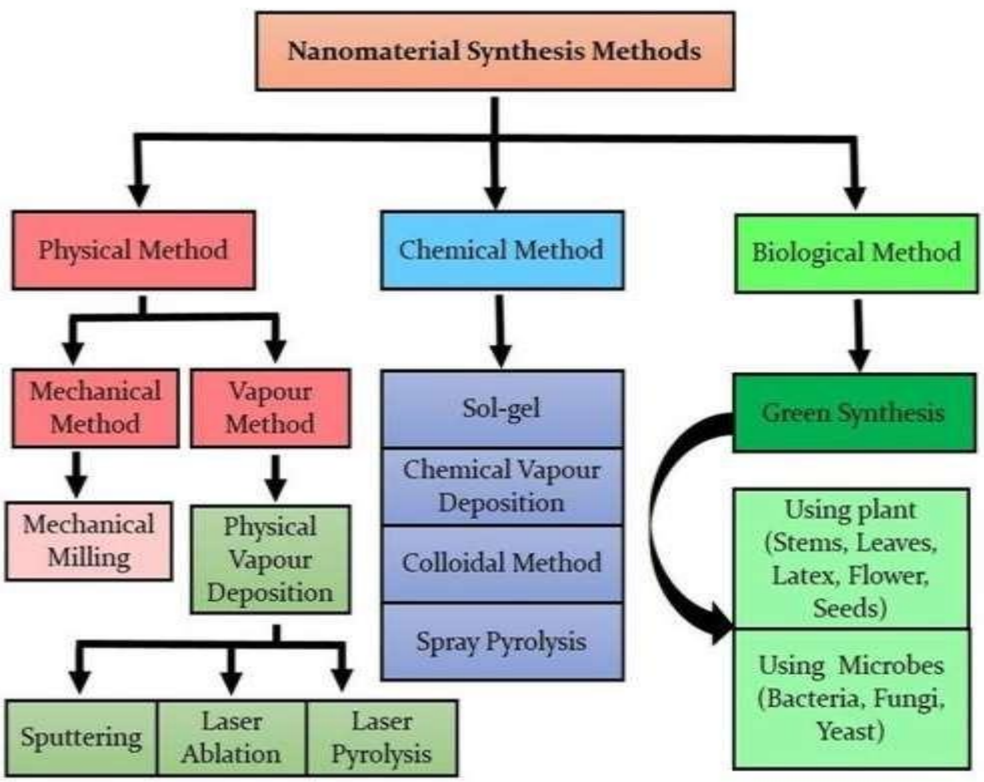
This method is based on the assembly and construction of nanoparticles from smaller particles (atoms and molecules). To obtain particles of the desired size and shape, this method depends on the variables of the chemical reaction and the type of control system used for each assembly reaction.

The process begins at the atomic level, and molecules are built with extreme precision through the self-assembly of atoms, in which the atoms arrange themselves in a specific configuration governed by their molecular nature. The modern semiconductor industry relies on crystal growth, which provides a good example of this self-assembly process (self-growth).



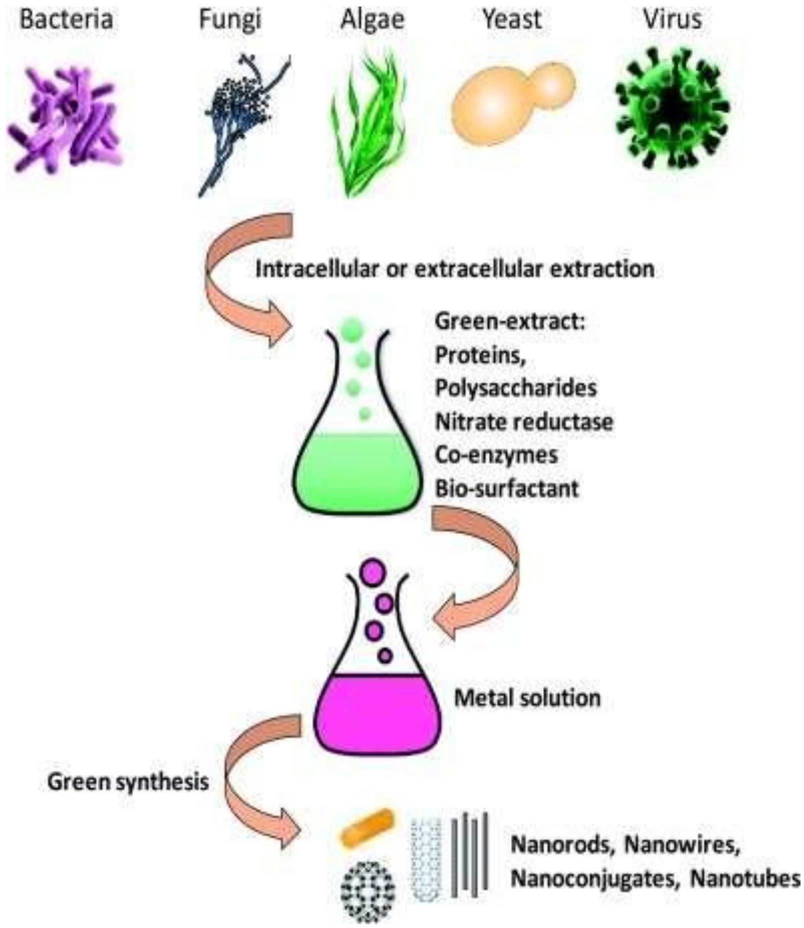
Of these main methods, three established approaches emerge for manufacturing nanoparticles of all shapes, sizes, and materials. These three approaches are:

1- Biological methods;
2- 2- Physical methods; and
3- Chemical methods.



Biological Methods of Nanoparticle Synthesis

It is one of the simplest, easiest, and cheapest methods, and it is environmentally friendly, hence its name, "green methods." It is a bottom-up manufacturing process. Green processes for producing nanoparticles have evolved to become a major branch of nanotechnology. Microorganisms such as bacteria, fungi, yeasts, and algae can be used, and various parts of plants are also widely used to prepare different nanomaterials.



1-Use of bacteria

Living organisms participate in the synthesis of nanoparticles by reducing ions and converting them into nanoscale metals in the presence of enzymes produced by cellular activity through electron transport. The internal or external formation of nanoparticles depends on their location. Intracellular nanoparticle formation occurs in the presence of enzymes due to the electrostatic interaction between metal ions and positively charged groups in the enzymes (proteins) of the cell wall. Extracellular nanoparticle formation occurs through the trapping of metal ions on the cell surface and their reduction in the presence of enzymes.

The biosynthesis mechanism of nanoparticles involves three steps: metal ion trapping, bioreduction, and particle synthesis. The reduction of metal ions to metal atoms occurs through reducing enzymes such as nitrate reductase, which is NADPH-dependent.

On the seabed and under anaerobic conditions, magnetobacteria utilize protein-coated magnetic particles to synthesize magnetic iron oxide nanoparticles. In the laboratory, magnetic particles with diameters of 20–45 nm, used in various medical applications, can be produced using bacteria. Another example of nanoparticle synthesis using bacteria is the extracellular synthesis of 10–20 nm gold nanoparticles using the photosynthetic bacterium ***Rhodopseudomonas capsulata***. Extracellular palladium nanoparticles have also been produced using Pseudomonas bacteria.

2-**Using Fungi**

The process of manufacturing nanoparticles within fungal cells involves the reduction of metal ions through several stages aided by cell wall enzymes. Negatively, metal ions are adsorbed onto the surface of the fungal cells, then reduced to their neutral atomic form, after which the particles are formed. However, in some cases, the ions can pass through the fungal cells and be reduced by enzymes on the cell membrane or within the cytoplasm. For example, the silver ion acts as a substrate bound to a reduction enzyme, which converts NADPH to NADP, releasing electrons that are used to convert the material to the nanoscale.
It can also be produced outside the cell with the help of the enzymatic activity of NADPH. An example of this is the production of stable, sized silver nanoparticles using fungal extracts that reduce silver ions to metallic molecules and form the nanoparticles. These nanoparticles are stable for long periods due to the reductive activity of NADPH. Various types of fungi have been found to contribute to nanoparticle production, such as *Aspergillus* sp
For example, Fusarium oxysporum and Penicillium sp. have been used to prepare silver nanoparticles. Spherical nanoparticles were also produced by adding zinc nitrate salt to the *Aspergillus fumigatus* filtrate.

3) Use of Algae

Stabilized NPs produced from algae have gained significant importance due to their lower toxicity, ease of handling, and cost-effectiveness. They also grow rapidly. Algae possess the ability to over-accumulate minerals and convert them into NPs, indicating their potential as an ideal choice for green synthesis. Bioengineered algal NPs have been used in numerous biomedical applications, including antibacterial, antioxidant, free radical scavenging, antifungal, and anticancer properties. Among all algal species, Turbinaria conoides is one of the most widely used for NP synthesis. Various shapes have been prepared, such as multi-dispersed, rectangular, round, and triangular NPs. Extracellular gold nanoparticles (95%) have also been prepared from the alga ***Sargassum wightii***.

Using extracts from different parts of the plant to synthesize nanomaterials

Plant extracts from various parts of plants, such as leaves, stems, roots, peels, seeds, and flowers, as well as from medicinal and herbaceous plants, have been used to synthesize nanoparticles. In this process, metallic nanoparticles are reduced by organic compounds found in plants, such as flavonoids, amino acids, carboxylic acids, ketones, phenols, and proteins. These substances act as effective reducing agents for producing nanoparticles.

An example of manufacturing nanomaterials using plant extracts is the use of an aqueous extract of ginger root (Zingiber officinale). This was achieved by heating a mixture of the plant extract with silver nitrate ($3AgNO_3$) at 60°C, resulting in silver nanoparticles measuring 20.4 nm.

The aqueous extract of beetroot (Beta vulgaris) was used to synthesize silver nanoparticles. The root extract was added to a silver nitrate solution, and the mixture changed color to dark brown, indicating the formation of silver nanoparticles. Gold nanoparticles (AuNPs) were synthesized using a fern root extract. The mixture gradually changed color to red, indicating the formation of spherical gold nanoparticles with dimensions of 5–20 nm. Spherical zinc oxide nanoparticles with diameters of 25–40 nm were produced using a radish extract. Plant leaves have also been widely used in the biosynthesis of silver nanoparticles. Some researchers used the aqueous extract of zederberry leaves (Melia azedarach L.) in their synthesis, producing spherical particles ranging in size from 18–30 nm.

The aqueous extract of rosemary (Rosmarinus officinalis) leaves was also used to synthesize sulfur nanoparticles with a size of 5-80 nanometers.