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# An Overview of the Categorization, Characterization, Production, and use of Nanoparticles

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**Abstract**
Nanotechnology has permeated many industries because to its distinct and obvious effects, which have led to many medicinal, agricultural, and other scientific discoveries. Nanomaterials (NMs) are used to improve technology because their physical, chemical, and biological properties can change and they work better than bulk materials. NMs are put into groups based on their size, shape, origin, and what they are made of. Each categorization's ability to predict NMs' distinctive traits increases their worth. Demand for NMs rises with production and industrial usage. Nanoparticles are particles having one or more diameters between 1 and 100nm, according to ISO and ASTM standards. Nanoparticles that are organic, inorganic, or made of carbon have better properties than bigger materials. Nanoparticles have better qualities like high reactivity, strength, surface area, sensitivity, stability, and so on because they are so small. For research and commercial usage, nanoparticles are synthesised through physical, chemical, and mechanical procedures, which have improved over time. Nanoparticle kinds, characteristics, production techniques, and environmental applications are reviewed in this work.

**Keywords:** Nanotechnology, Nanoparticles, Synthesis, Nano engineering

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## Introduction

Nanotechnology alters structures, electronics, and systems at the nanoscale scale (1 nm to 100 nm (10-9m)) [1,2]. Nanometer comes from the Greek word "nano" meaning "extremely tiny" [3]. Their compact size offers them larger surface areas, better reactivity, and tuneable features [4-6]. These unique features have spurred nanoscience and the use of NPs in biomedicine, cosmetics, electronics, food analysis, environmental remediation, and painting [7-11]. Nanoscale science and engineering provide atomic and molecular comprehension and control [12]. People are interested in nanoparticles because of their electrical, optical, and magnetic properties [13]. These NPs are the size of nanoengineering [14,15]. Nanoparticle research is driven by new ways to store data, treat diseases, and deliver drugs [16–19]. Core/shell (CS) NPs, polymer-coated NPs, Ag-NPs, Cu-NPs, Au-NPs, Ni-NPs, Pt-NPs, CuO-NPs, ZnO-NPs, Pd-NPs, Si-NPs, FeO-NPs, ZrO2-NPs, and TiO2-NPs are all types of metal, metal oxide, and dioxide NPs. [20-23].

## Nanoparticle Classification

Nanomaterial categorization methods vary. One, two, and three-dimensional nanoparticle classifications [24].

### One dimension nanoparticles

Electronics, chemistry, and engineering have employed thin film and fabricated surfaces for decades. At the moment, thin films (1-100 nm) or monolayers are used in solar cells and catalysis. Thin films are used in information storage systems, sensors for chemicals and living things, fiber-optic systems, and magneto-optic and optical devices.

### Two dimension nanoparticles Carbon nanotubes (CNTs)

Carbon nanotubes are made up of a hexagonal network of carbon atoms that are 1 nm wide and 100 nm long, about the same size as a layer of graphite rolled up into a cylinder. Single-walled carbon nanotubes (SWCNTs) and multi-walled carbon nanotubes (MWCNTs) are the two types of CNTs. Carbon nanotubes are unique materials because of their small size and their unique physical, mechanical, and electrical properties [25]. Depending on how the carbon leaf is wound on itself, they have metallic or semiconductive properties. Nanotubes can carry very high amounts of current, up to a billion amperes per square metre, which makes them a superconductor. Carbon nanotubes are sixty times stronger than the best steels in terms of how they hold together. Carbon nanotubes are very good at absorbing molecules and are set up in a three-dimensional way. They are also very stable chemically and chemically.

### Three dimension nanoparticles

#### Fullerenes (Carbon 60)

Fullerenes are spheres made up of anywhere from 28 to 100 carbon atoms and C60. This soccer ball is made of pentagons and hexagons made of carbon. Fullerenes are uncommon materials. They can withstand high pressure and recover. These molecules do not mix, making them promising lubricants. Their electrical qualities make them suitable for data storage and solar cell manufacture. Nanoelectronics may benefit from fullerenes. Fullerenes may be loaded with various chemicals and used in medicine [26].

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**Dendrimers**

Dendrimers are new polymers with controlled nanoscale structures. Drug delivery and imaging dendrimers are between 10 and 100 nm in size and have a lot of functional groups, which makes them good for delivering drugs to specific areas [27].Dendrimers are widely understood. Dendrimers may encapsulate medicinal or diagnostic substances [28]. They are essential for large-scale production of 1–100 nm organic and inorganic nanostructures [26]. They are compatible with DNA and may be made into metallic nanostructures, nanotubes, or encapsulation [29]. Dendrimers are widely used in medical and biological disciplines because of their nanostructure and compatibility with organic structures like DNA. Dendrimers are used in nonsteroidal anti-inflammatory drugs, antibacterial and antiviral drugs, anticancer agents, pro-drugs, and high-throughput drug discovery screening agents[30]. The positive charge on dendrimers can break cell membranes, which makes them dangerous [31].

**Quantum Dots (QDs)**

Free electrons are in quantum dots. QDs are 2–10 nm colloidal semiconductor nanocrystals. Electrochemistry or colloidal synthesis may produce QDs from semiconductor materials. CdSe, CdTe, InP, and InA are the most frequent QDs (InAs). Quantum dots might contain one electron or many. Electrons may be precisely sized, shaped, and numbered. They are either semiconductors, insulators, metals, magnetic materials, or metallic oxides. It is used for quantum computing, storing information, and making optoelectronic devices. Quantum dots that are coded by colour speed up DNA testing. Electrons and hole carriers are confined in quantum dots (QDs) below the Bohr radius. Atoms from groups II and VI (CdSe, CdS, and CdTe) or II and V are found in QD nanocrystals (In P). The ZnS and CdS shells may stop excitons in the emissive core from being slowed down by the surface. This could improve the core's photostability and emission quantum yield [32]. QDs have a lot of space on the outside where therapeutic agents can be attached for simultaneous drug delivery, imaging in vivo, and tissue engineering [33].

**Nanoparticle Synthesis**

Bottom-up or top-down approaches synthesize nanoparticles. Process is simplified in (Figure:1)

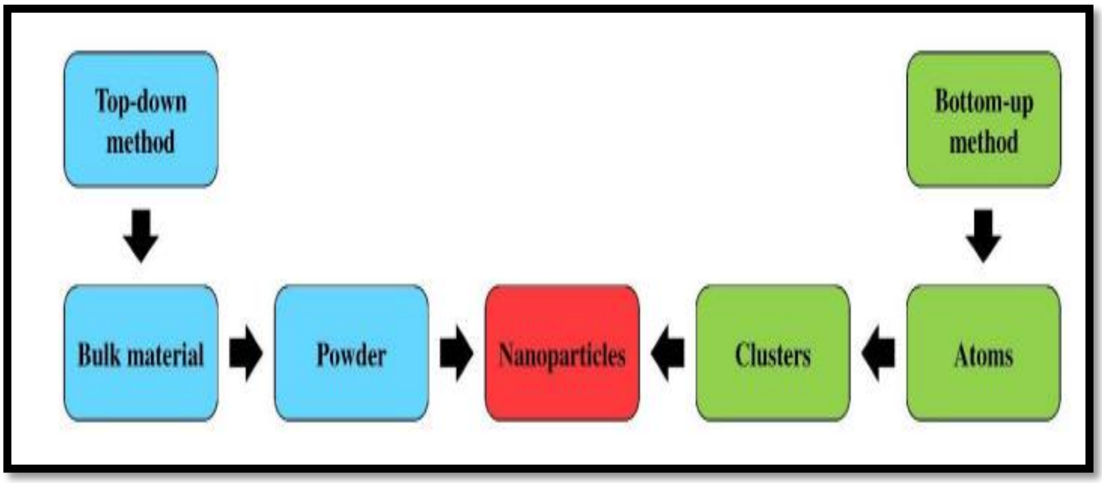


Fig:1 Synthesis process of nanoparticles

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**Bottom-up**

From atoms to clusters to nanoparticles, the "bottom-up" or "constructive" method builds things. Sol-gel, spinning, CVD, pyrolysis, and biosynthesis are the most common bottom-up ways to make nanoparticles.

**Top-down**

Top-down methods that are destructive break up big pieces of material into tiny pieces called nanometrics. Nanoparticles are often made by mechanical milling, nanolithography, laser ablation, sputtering, and thermal breakdown.

**Biosynthesis**

Biosynthesis of nanoparticles that are safe and biodegrade is good for the environment [34]. In biosynthesis, bacteria, plant extracts, fungus, and precursors are used instead of chemicals to make nanoparticles for bioreduction and capping. Biosynthesized nanoparticles have properties that are different and better for biomedical uses [35].

**Physical**

The physical and optical properties of a nanoparticle include its colour, its ability to let light in, absorb it, and reflect it, as well as its ability to absorb and reflect UV light in a solution or on a surface. Their use is also affected by how elastic, ductile, tensile, and flexible they are. Modern things can be water-loving or water-hating, be suspended, spread out, or settle. The magnetic and electrical properties of nanoparticles, such as their conductivity, semiconductivity, and resistivity, have made it possible for them to be used in modern electronics and in the thermal conductivity of renewable energy.

**Chemical**

Chemical applications depend on how well the nanoparticles react with the target, how stable they are, and how sensitive they are to things like water, the environment, heat, and light. The antibacterial, antifungal, disinfecting, and toxicological properties of nanoparticles are useful in biomedical and environmental applications. Nanoparticles' ability to corrode, oxidise, reduce, and catch fire affects how they are used.

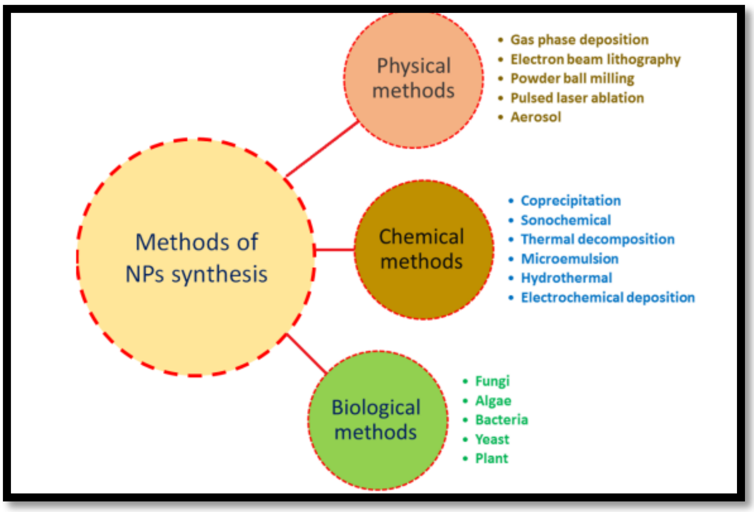


Fig:2 Nanoparticle generation diagram

## Characterization of Nanoparticles

### UV–visible spectrometry

UV-visible spectroscopy was used to look at how different nanoparticles were made using different methods. With increasing reaction time and concentration of biological extracts with salt ions, there is a steady rise in the characteristic peak, which shows that nanoparticles are being made. The surface plasmon resonance is shown by peaks in the UV-vis absorption spectrum of nanosized particles [36].

### X-ray diffraction (XRD)

X-ray fluorescence looks at the elements in a material without destroying it. X-ray diffraction patterns have been used for a long time to figure out the crystalline phases of a compound. The sample's properties may be shown by the angle and intensity of the XRD beam diffraction [37].

### Fourier transformation infrared spectroscopy (FTIR)

FTIR is often used to compare molecules and find the functional groups in pure substances and mixtures. The vibrations of atoms and molecules are linked by infrared analysis [38].

### Transmission Electron Microscopy (TEM)

TEM captured nanoparticle morphology. TEM uses electron transmittance to deliver bulk material information from low to high magnification. TEM shows the quadrupolar hollow shell structure of NPs [39].

### Scanning Electron Microscopy ( SEM)

SEM measures magnetic nanoparticles. In its normal mode, SEM captures secondary electrons created by the sample when the electron beam hits it instead of electrons passing through it. This lets it make pictures in three dimensions. [40]

### Dynamic light scattering (DLS)

Photon-correlation spectroscopy (PCS), also called "dynamic light scattering," is the fastest and most common way to measure particle size (DLS). DLS is often used to measure Brownian nanoparticles in colloidal solutions that are nano and submicron in size. When monochromatic laser light hits a solution of Brownian-moving spherical particles, the wavelength changes because of a Doppler shift. Particle size affects this. Using the autocorrelation function and the particle's diffusion coefficient, the size distribution and medium motion may be extracted. The most common DLS-based particle size and size distribution estimate method is photon correlation spectroscopy (PCS) [41]. SEM: SEM directly visualises morphology. Electron microscopy methods are useful for morphological and sizing investigation, But they don't give the size distribution or average population. For SEM characterization, the nanoparticles solution should be dried into a powder, put on a sample holder, and sputtered coated with a conductive metal like gold. The material is scanned by a tiny electron beam [42]. Secondary electrons from the surface of the sample show what it looks like. Nanoparticles have to work in a vacuum, and the electron beam could hurt polymer. The average sizes from SEM and dynamic light scattering are about the same. These methods cost a lot of money, take a long time, and need data on size dispersion [43].

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**Atomic force microscopy (AFM)**

Atomic force microscopy (AFM) uses a probe tip that is only a few atoms wide to scan materials at the sub-micron level [44]. Instrument creates sample topography based on the forces at the sample tip. Samples are scanned in either contact mode or noncontact mode, depending on how good they are. In contact mode, the probe taps the sample surface to produce the topographical map. In non-contact mode, the probe hovers above the conducting surface. AFM can photograph sensitive biological and polymeric nano and microstructures without any special treatment [45]. AFM describes size and size distribution most accurately without math. AFM particle size also helps explain biological circumstances [46].

**Applications of Synthesis NPs**

**Water treatment**

Ionic water can be cleaned up with nanotechnology [47]. Nanostructured materials with a high aspect ratio, the ability to react, a controlled pore volume, and electrostatic, hydrophilic, and hydrophobic interactions are used in adsorption catalysis, sensing, and optoelectronics [48,49]. Nanoscale silver, titanium, gold, and iron metals and oxides are used to protect the environment [50]. Bacteria, viruses, and fungi can all be killed by Ag-NPs [51,52].

**Drug delivery**

Nanoparticles improve the solubility, stability, biodistribution, and effectiveness of free drugs [53,54]. Nanoparticles may be used as pharmaceutical delivery methods due to their benefits. Mixed monolayer shielded metal clusters delivered hydrophobic fluorophores in vitro [55,56]. Nanostructures have been created for drug delivery. Liposomes, micelles, Ag-NPs, quantum dots, Au-NPs, silica NPs, and drug nanocrystals are examples of drug nanocarriers [57]. SPIO-NPs transported peptides, DNA molecules, chemotherapeutic, radioactive, and hyperthermic drugs [58]. Numerous research have exploited IO-NPs as nanocarriers for drug and gene delivery [59,60].

**Antimicrobial**

Recently, pathogenic bacteria have developed antibiotic resistance, presenting a major threat to the healthcare industry[61,62]. Nanotechnology and biological sciences provide smart surfaces that minimise infection. Nanotechnology-based solutions may help produce materials that restrict or prevent airborne virus droplets in biomedical devices and medical personnel protective equipment [63]. Several studies [64–70] have shown that antimicrobial coatings made of Au-NPs, Se-NPs, Ag-NPs, MgO-NPs, CuO-NPs, $TiO_2$-NPs, and ZnO-NPs work well. No one knows if metal-oxide nanoparticles can kill bacteria. Bacteria can be killed by high levels of ions, oxidative stress, ROS, and damage to the membrane [71–74].

**Catalysis**

Ca Large surface areas of nanoparticles allow for catalytic activity. Nanoparticles' high surface-to-volume ratio makes them efficient catalysts for chemical synthesis [75]. Due to their huge surface area, platinum nanoparticles in automobile catalytic converters minimise platinum consumption, cutting cost and improving performance. Nickel oxide is converted to Ni by nanoparticles in a number of chemical reactions.talysis

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**Medicine**

Nanoparticles in medication delivery have benefited medicine. Nanoparticles deliver drugs to particular cells [76]. Placing the medicine in the right place and dose reduces drug intake and negative effects. It's cheaper and safer. Nanotechnology may improve tissue engineering. Tissue engineering replaces artificial implants and organ transplants. Carbon nanotube scaffolds can generate bones [77]. Medicine has always used gold. Gold is employed in numerous Ayurvedic treatments. Memory improvement using gold is widespread. Certain medicinal medicines include gold to improve a baby's mental health [78].

## Prospects and challenges

Successful medication delivery techniques use nanoparticles. Nanoparticles are an important tool in nanomedicine for medication targeting, delivery, and diagnostics and treatment. Developing these approaches presents various technological challenges. Nanochips for nanoparticle release, biomimetic polymer architecture, control of sensitive drugs, functions (active drug targeting, bioresponsive triggered systems, systems interacting with me body smart edelivery), and carriers for advanced polymers for therapeutic peptide/protein delivery are some examples of the technologies mentioned above. Methods for controlled medication distribution have been developed. Nanoscale components are used in the majority of key drug delivery formulation and dispersion research programmes.

## Conclusion

Nanotechnology improves common items' performance and efficiency. It cleans the air, water, and energy for a sustainable future. Top institutions, corporations, and organisations are investing more in nanotechnology research. Research on nanotechnology has come a long way. It is being tried out for new uses to improve its efficiency, performance, and cost so that everyone can use it. Nanotechnology's efficiency and eco-friendliness make it promising. Different nanoparticles have helped nanotechnology progress. Due to advances in new nanomaterials and their applications, scientists interested in such techniques have produced nanocomposites. This article explained nanotechnology and how to make nanomaterials from metals, metal oxides, graphene oxides, and polymers. Plant extracts and microorganism biomolecules are fascinating nanoparticle manufacturing technologies with little or no toxicity. Nanotechnology-enabled medicine delivery is transforming pharmaceutics. Nanotechnology will alter medicine distribution across all routes, from oral to injectable. Poor bioavailability in modern pharmaceutics increases patient expenditures, treatment inefficiency, and toxicity or mortality. Nanotechnology is ideal for developing medication delivery methods for microscopic body parts. Nano-enabled drug delivery allows medications to pass through cell membranes, which is crucial to genetic medicine's progress in the next years. Nanotechnology-enabled medication delivery could minimise drug toxicity, cost, bioavailability, and extend the economic life of unique pharmaceuticals for physicians and patients.

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