Synthesis of Nanomaterials
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Centre for Nanoscience and Technology
Aryabhatta Knowledge University, Patna
Mithapur, Patna
Bihar

Content developed by: Dr. Vijay Kumar Ravi

Biochemical Synthesis of Metal Nanoparticles (NPs)

- **Owing to the physiochemical properties and many applications of nanoparticles, extensive efforts have been develop for suitable synthetic techniques for producing nanoparticles.**
- **However, various physiochemical approaches for the synthesis of metal nanoparticles are limited by the environmental pollution caused by heavy metals.**
- **Synthesizing nanoparticles through biological process routes, has the advantages of nontoxicity, reproducibility in production, easy scaling-up, and well-defined morphology.**
- **In particular, microorganisms and plants have been demonstrated as new resources with considerable potential for synthesizing nanoparticles.**
- **Several microorganisms, including bacteria, fungi, and yeast, as well as plants, have been explored for the synthesis of metal nanoparticles.**
- **It has become a new trend in nanoparticle production.**

Terminology used in Biochemical Method of Synthesis

- **Biological nanoparticles: Nanoparticles synthesize from biological sources, such as microorganisms and plant extracts.**
- **Biocompatibility: The compatibility and non injurious effects of metal nanoparticles within the human body or healthy living cells.**
- **Biological nanofactories: Biological sources capable of synthesizing metal nanoparticles, including microorganisms and plants.**
- **Biological synthesis: Synthesis using natural sources, avoiding any toxic chemicals and hazardous by products, usually with lower energy consumption.**
- **Mycosynthesis: Biological synthesis of metal nanoparticles using fungi.**
- **Phytonanotechnology: The biological synthesis of metal nanoparticles from plant resources, which further includes the optimization and applications of synthesized nanoparticles.**

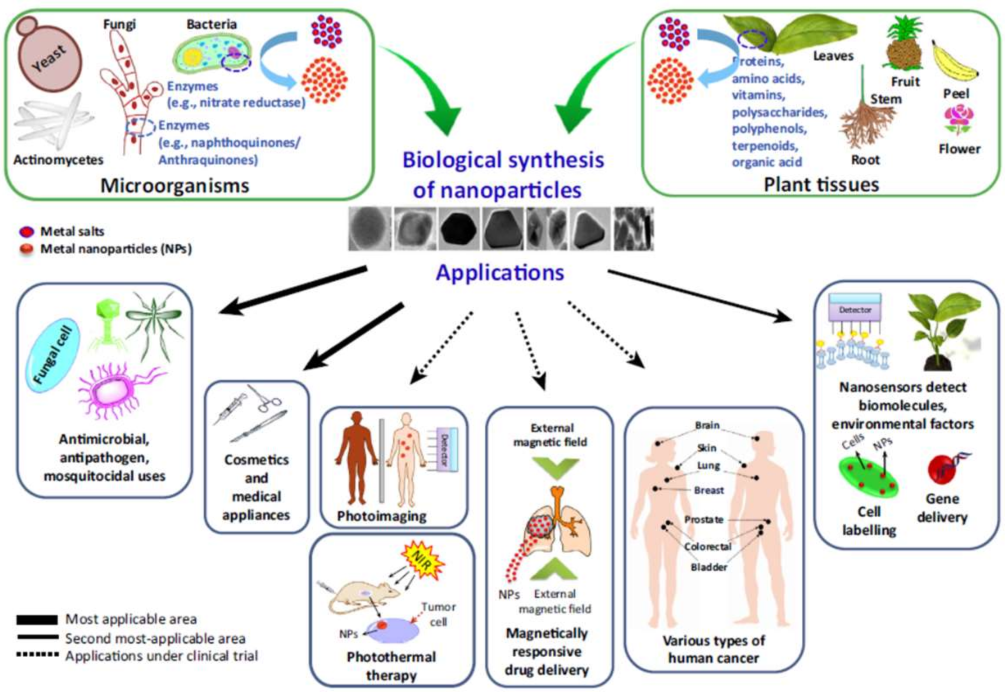
Biological Synthesis and application of Metal Nanoparticles

Right Figure : Biological Synthesis and Applications of Metal Nanoparticles in Biomedical and Environmental Fields.

- **Silver nanoparticles are mostly used in the medical field due to their antimicrobial effect, and zinc and titanium nanoparticles are used in cosmetics. Silver, zinc, and other metal nanoparticles are also used in food packaging, wound dressings, catheters for drug delivery, and so on, due to the broad range of antimicrobial effects.**

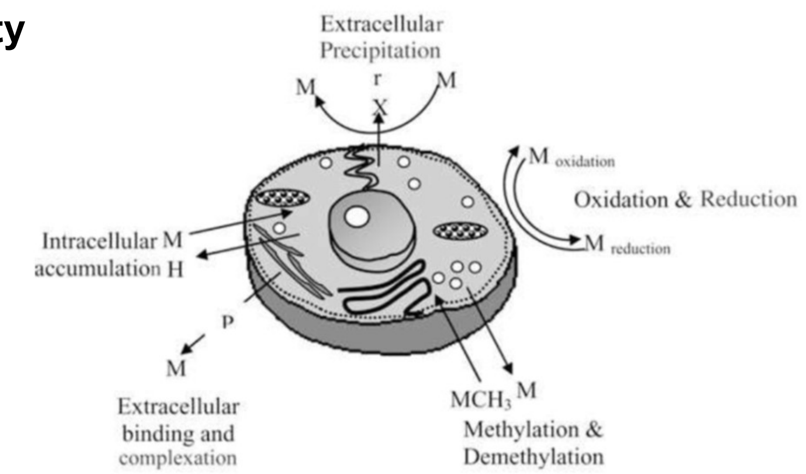
- **The second application area of biological nanoparticles is the development of sensors for various biomolecules related to environmental factors and agriculture.**

- **Furthermore, nanoparticles are also used in gene delivery and cell labeling in plants and in medicine. Some applications of metal nanoparticles are still in development, such as photoimaging, photothermal therapy, and magnetically responsive drug delivery.**



Nanoparticle Synthesis Using Microorganisms

- **Microorganisms equipped with important nanofactories that has immense potential such as ecofriendly, cost-effective tools, avoiding toxic, harsh chemicals and the high energy demand required for physiochemical synthesis.**
- **Microorganisms have evolve the mechanism to accumulate and detoxify heavy metals due to various reductase enzymes, which are capable to reduce metal salts to metal nanoparticles with a narrow size distribution.**
- **And, therefore, less possibility to produce polydispersity**



NPs Synthesis using microorganism

- Over the past few years, microorganisms, including bacteria (such as actinomycetes), fungi, and yeasts, have been studied extra- and intracellularly for the synthesis of metal nanoparticles.

- Some of microorganisms liberate hydrogen sulphide. It can oxidize organic matter forming sulphate, which acts like an electron acceptor for metabolism.

- This hydrogen sulphide in presence of metal salt, convert metal ions into metal sulphide, which deposits extracellularly.

- The metal ions are converted into a non-toxic or less toxic form and covered with certain proteins in order to protect the remainder of the cell from toxic environment.

- Some microorganisms are secreting some polymeric materials like polysaccharides.

- They have some phosphate, hydroxyl and carboxyl anionic groups which complex with metal ions and bind extracellularly.

Synthesis and application of Biological NPs from microorganism

Microorganism	Extracellular/ Intracellular	Types of Nanoparticle	Shapes	Size (nm)	Applications
Bacteria					
Pseudomonas deceptionensis	Extracellular	Silver	Spherical	10–30	Antimicrobial and antibiofilm
Weissella oryzae	Intracellular	Silver	Spherical	10–30	Antimicrobial and antibiofilm
Bacillus methylotrophicus	Extracellular	Silver	Spherical	10–30	Antimicrobial
Brevibacterium frigoritolerans	Extracellular	Silver	Spherical	10–30	Antimicrobial
Bhargavaea indica	Extracellular	Silver and gold	Silver anisotropic; gold, flower	30–100	Antimicrobial
Bacillus amyloliquefaciens	Extracellular	Cadmium sulfide	Cubic/hexagonal	3–4	–
Bacillus pumilus, *Bacillus persicus*, and *Bacillus licheniformis*	Extracellular	Silver	Triangular, hexagonal, and spherical	77–92	Antiviral and Antibacterial
Listeria monocytogenes, *Bacillus subtilis*, and *Streptomyces anulatus*	–	Silver	Anisotropic	Varied shape and sizes	Antimicrobial and mosquitocidal
Fungus					
Neurospora crassa	Intra- and extracellular	Silver, gold, bimetallic silver and gold	Quasi-spherical	>100	–
Actinomycetes					
Streptomyces sp. LK3	–	Silver	Spherical	5	Acaricidal
Yeast					
Yarrowia lipolytica NCYC 789	Extracellular	Silver	Spherical	15	Antibiofilm
Rhodosporidium diobovatum	Intracellular	Lead	–	2–5	–
Extremophilic yeast	Extracellular	Silver and gold	Irregular	Silver, 20; gold,30–100	–
Candida utilis NCIM 3469	Extracellular	Silver	Spherical	20–80	Antibacterial

Plant Taxonomic groups used for green Synthesis of different Metallic NPs

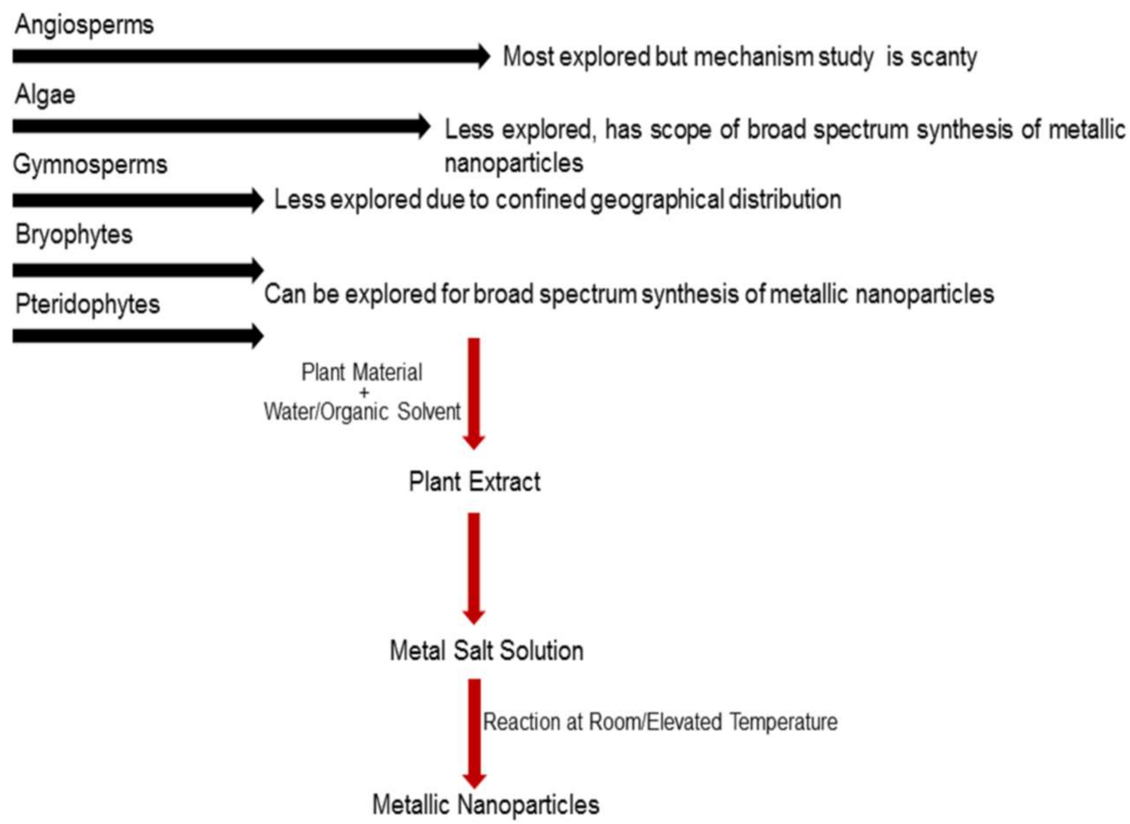
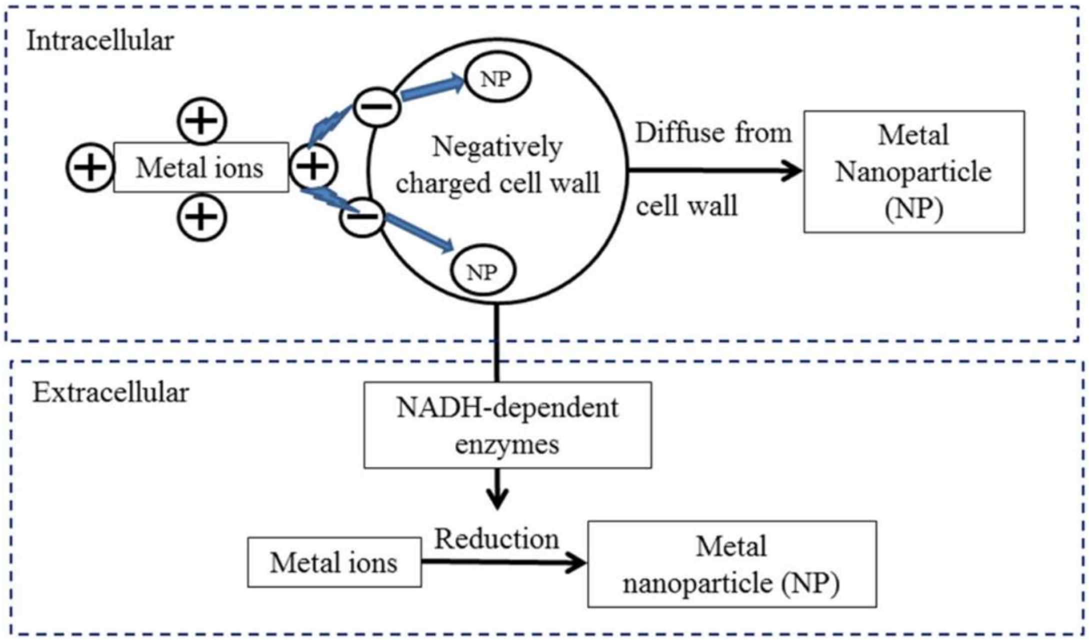


Fig.(right): Flow chart of plant taxonomic groups used for green synthesis of different metallic nanoparticles.

Intracellular and Extracellular Synthesis of NPs by bacteria



Scheme source: Nanotechnol. Environ. Eng. (2017) 2:18

Experimental Steps for Producing Nanoparticles from Microorganisms

- **Microorganisms are likely synthesize nanoparticles either extracellularly or intracellularly.**
- **In extracellular synthesis: First step is culturing the microorganisms for 1–2 days in a rotating shaker under optimum conditions (including pH, temperature, medium components, etc.),**
- **Second Step is centrifuge the culture to remove the biomass. Take supernatant (upper layer of microorganism solution) which is used to synthesize nanoparticles**
- **Add a filter-sterilized metal salt solution in supernatant and further incubate it for a time.**
- **The nanoparticle synthesis can be confirmed by observing a change in the color of the culture medium.**
- **For silver nanoparticles, the color changes to deep brown, whereas, for gold nanoparticles, it changes from ruby red to a deep purple color.**
- **NPs formed product again incubate, then reaction mixture can be centrifuged at different speeds to remove extra medium components or large particles.**
- **Finally, the nanoparticles can be centrifuged at high speed or with a density gradient**
- **Washed thoroughly in water/solvent (ethanol/methanol) and collect the pellet deposited at bottom.**

Experimental Steps for Producing Nanoparticles from Microorganisms

- Intracellular synthesis of nanoparticles:
- Culture the microorganism for a certain optimum growth time.
- Biomass is collected by centrifugation and washed thoroughly with sterile water.
- Then dissolved in sterile water with a filter-sterilized solution of metal salt.
- Similar to extracellular synthesis, the reaction mixture is monitored by visual inspection for a color change.
- After the incubation period is over, the biomass is removed by repeated cycles of ultrasonication, washing, and centrifugation.
- These steps help to break down the cell wall and enable the nanoparticles to be released.
- The mixture is then centrifuged, washed, and collected.

To be continued-------

References

- **R. K. Das, V. L. Pachapur, L. Lonappan, M.itra Naghdi, R. Pulicharla, S. Maiti, M. Cledon, L. Martinez-Araceli Dalila, S. J. Sarma, S. K. Brar Biological synthesis of metallic nanoparticles: plants, animals and microbial aspects. Nanotechnol. Environ. Eng. (2017) *2*,2-21.**
- **P. Singh, Yu-Jin Kim, D. Zhang, Deok-Chun Yang Biological Synthesis of Nanoparticles from Plants and Microorganisms. Trends in Biotechnology, (2016), *34*, 588-599.**