Insight into the recent progress of Ag/Au-based nanomaterials-synthesis, characterising tools and bio-applications

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Abstract:

Nanomedicine, known as a nanotechnology-based biological application, is concerned with synthesizing, characterization, and functionalizing unique the for targeted drug delivery from the pharmaceutical industry. Silver (Ag) and gold (Au) nanoparticles (NPs) are important due to the unique properties that make them useful in various fields. Ag-NPs are known for their excellent antimicrobial properties, while Au-NPs have unique electronic and optical properties that make them useful in catalysis, electronics, imaging, and sensing. Ag and Au-NPs have potential applications in nanomedicine, including drug delivery, cancer therapy, and imaging. This review covers the synthesis of Ag and Au-NPs using chemical, physical, and biological methods. Biosynthesis methods are preferred over chemical and physical methods. Characterization of the nanoparticles was done using various techniques, including X-ray diffraction, UV-VIS, FTIR, DLS, XPS, SEM, and TEM analysis. The review also discusses the nanoparticles' potential applications, including antimicrobial activity, regenerative medicine, and cell therapy. In the future, Ag and Au-NPs will have potential applications in medical treatments, environmental remediation, energy production, electronics, and advanced materials development. Ongoing research into their properties and capabilities could lead to significant advances in these fields.

1. Introduction:

The development of nanotechnology has been accelerated by the introduction of nanomaterials, specifically inorganic nanoparticles (NPs) and nanorods, which possess unique properties and physicochemical characteristics that are distinct from their bulk counterparts and are size-dependent. Current nanotechnology focuses on nanostructures that are smaller than 100 nanometers in at least one dimension and that can be altered at the atomic or molecular level. Early symptom diagnosis and treatment in clinical and environmental research have huge potential thanks to the interdisciplinary study field that combines chemistry, biology, engineering and medicine.[1,2].The term "nano" is used to describe objects or structures that are extremely small, with dimensions measured in nanometers, which is one billionth of a meter[3].Metallic materials have long attracted researchers at the nanoscale level (metallic nanoparticles). They are now using them in a wide range of applications in many different industries, including engineering, agriculture, medicine, etc[4,5].When compared to macromolecules, nanoparticles (0.1-100 nm) have distinct physical and chemical properties. A recent development in nanotechnology has a wide range of medical uses. Researchers have been interested in the environmentally safe and nontoxic process of biological nanoparticle manufacturing. Due to their greater surface area, nanoparticles offer stronger interactions with microbial agents. Moreover, nanoparticles have a greater ability than conventional macro- and microparticles to enter bacterial cells and display bactericidal activity[6].These benefits make nanoparticle systems potential medicinal agents.

Both organic and inorganic functional groups have a significant impact on the surface modifications that occur on the atoms of desired metals or metal oxides.. This method not only prevents oxidation and agglomeration of nanoparticles but also enables improved functionalization[7].By connecting with the surfaces of other molecules, solids, or nanoparticles, simple organic molecules or groups provide nanoparticles with sufficient potential protection against agglomeration [8].This will enable NPs to approach a desired biological organism. If they are coated with biological molecules, they might be able to adhere to a cellular division's surface and form a link with it, offering a precise means of tracking or finding it.[9].In the biological sciences, using nanoparticles (NPs), primarily metals NPs, for therapeutic and diagnostic reasons has recently increased. The increase of NPs' application and purposes can be attributed to factors such as their distinctly small size, tremendous strong responsiveness to living tissues, high temperature stability, and cellular mobility are all characteristics of this material.[10].The size, shape, and morphology of nanoparticles determine their biological characteristics, and these factors may be affected by the synthesis process[11].It is possible to create nanoparticles through chemical, physical, and biological processes[12].Evaporation-condensation and laser ablation are examples of physical processes, while chemical approaches call for reducing and stabilizing agents[13].On the other hand, biogenic synthesis uses algae, fungi, plants, and microbes as reducing agents and is, therefore, more environmentally benign[14].

Due to their environmental friendliness, low cost, and very simple manufacture, syntheses of nanoparticles, especially Ag and Au, have attracted significant interest[15].Nanoparticles made of metal and metal oxide have several uses in the study of biomedicine and pharmaceuticals.Ag-NPshave been widely used in therapies, particularly in the practice of customized healthcare. Ag-NPs are frequently employed in tissue regeneration, medication administration, antibacterial therapy, and diagnostic procedures.Au-NPs have been extensively utilised in a variety of biomedical activities, including cancer treatment and diagnosis, targeted medication distribution, and bioimaging[16]. They are simple to produce and can be coupled with a variety of molecules and chemicals. Compared to other metal particles, such as Ag-NPs, they have better rates of penetration and are significantly less harmful. Au-NPsare the ideal material of choice for biomedicine because of their characteristics[17].Additionally, Ag-NPs have been successfully applied as antibacterial agents in a variety of ecological applications, fabric coatings, storage of food, and biopharmaceutical sectors.[18].Ag has, in fact, been used successfully to both prevent and treat infections brought on by a number of different microbes[19].Ag-NP-based conjugates with doxorubicin, fluorouracil, peptides, and folic acid, among other chemotherapeutic anticancer medicines, have been created so far as anticancer agents and for various cancer-related uses[20].It is obvious that Ag-NPs and their conjugates have a lot of promise for use in a variety of scientific and technological industries, especially in the medicinal and medicinal fields[21].From diagnosis to treatment, including biosensors, Au-NPsin a variety of shapes like nanostar, nanorod, nanocage, and nanosphere, have been investigated in a variety of biomedical applicationsincluding the delivery of drugs and genes[22-23], phototherapyalong with overheating[24], and antimicrobial applications[25-27].According to a previous study, Au-NPs between 10 and 30 nm in size implanted more readily into malignant tumor cells than bigger ones[28].Surprisingly, smaller diameters of 20 nm, as opposed to 40 and 80 nm, of surface-coated Au-NPs demonstrated a greater cell uptake[29].

This review concentrated on identifying recent exposure to Ag/Au-NPsrelevant synthesis,characterization, and bio-applications. The biomedical and healthcare implications of Ag-NPs have mostly focused on microbiological, fungus, antitumor, anti-oxidative, antivirus, and antihyperlipidemic applications. On the other hand, the key focus of Au-NPs was given towards biomedical applications such as regenerative medicine, cell therapy and antimicrobial activity. This reviewalso provides an overview of recent developments in the design of hybrid nanomaterials and discusses how they are mostly used in clinical and translational research. Furthermore, the review gave insight into the future direction of the research field relevant to the bio-application of Ag/Au-NPs in regenerative medicine.

2. Synthesis of Ag and Au-NPs

Researchers have been interested in Ag and Au-NPs (NPs) because of their distinctive features (for example size and form can vary based on optical, antibacterial, and electronic qualities). For the synthesis of Ag-NPs, many various synthesis techniques have been published [30]. Nanoparticle synthesis can be done physically, chemically, photochemically, or biologically. Furthermore, condensing and dispersing are the two categories under which colloidal nanoparticle solutions are prepared. Additionally, Laser ablation, cathode sputtering, and electric arc dispersion are examples of "top-down" dispersion techniques that work by destroying the material's crystal lattice. The chemical process is the basis for condensation techniques (reduction in solution, followed by nanoparticle precipitation, formation and stabilization)[31] **(Figure 1).**

The most used processes for creating nanoparticles are chemical ones. Certain chemical techniques, however, are unable to completely eliminate the synthesis protocol's use of harmful substances[32-33]. Since noble metal nanoparticles like Au andAgare frequently used in regions where people come into touch with them, there is an increasing need to create ecologically acceptable nanoparticle synthesis procedures that don't include hazardous chemicals. As potential environmentally benign biological techniques for creating nanoparticles utilising microbes are alternatives to chemical and physical processes[34-36], proteins [37], and plant extract or plants [38] have been proposed.This has raised awareness of biogenic synthesis techniques. These techniques make it is feasible to make NPs that have better physiochemical properties, more consistency, and lower toxicity[39].

2.1 **Preparation of Ag-NPs**

Firstly, the reviewwould discuss the key synthesis approaches of the Ag-NPs.In the chemical reduction methodfor synthesising Ag-NPs,initial concentrations of $AgNO_3$, reducing agent, $AgNO_3$ molar ratios, and stabiliser concentrations all have an impact on several metrics, including the particle size and aggregation state of Ag-NPs[40].Various reducing agentalong with suitable stabilizing agent are used for chemical reduction method such as Hydrazine hydrate and Sodium Dodecyl Sulphate (SDS);Citrate of sodium (performs both reducing and stabilising functions)[41]; ascorbic acid (reducing agent) and Cetyltrimethylammonium bromide (CTAB, stabilizing agent)[42];Trisodium citrate (reducing agent)[43-45]; andSodiumborohydrate (reducing agent)[46-48].Poly vinyl alcohol, Sodium citrate and Hydrogen peroxide (performs both reducing and stabilising functions)[49,50]; PVP, Ethylene glycol solution (performs both reducing and stabilising functions)[51]; Threonine (reducing agent), PVP and NaOH (stabilizing agent) [52]; L-alanine and ascorbic acid (reducing agent) [53].There are numerous ways that have been established for the chemical preparation of Ag-NPs, including the chemical reduction approach [54], the polyol method [55], and the radiolytic process [56]. Chemical reduction is the best and easiest way to produce nanoparticles that don't aggregate, have a high yield, and require little to no pre-treatment [57].

2.2 **Preparation of Au-NPs**

Synthesis of Au-NPs using various types of methods are discussed here. Au-NPs are also synthesised similar way to that of Ag-NPswith the help of reducing and stabilizing agents.Primarily the reviewfound out that the chemical synthesis method such as chemical method is the key synthesis strategy for having bio-graded NPs where both reduction (using substance such as borohydrides, amino boranes and one electronic reducing substances such as electron-rich transition metal sandwich complexes) and followed by stabilization (using substances such as trisodium citrate dihydrate) are performed subsequently[58]. Turkevich method, for reducing $HAuCl_4$ with citrate in aqueous, is one of the most well-known methods for producing Au-NPs [59]. During time, the solution progressively changes from bright yellow to wine red.By using this technique, Au-NPs with a diameter of roughly 20 nm are produced. Citrate ions act as both stabilizing and reducing agents [59,60], Brust-Schiffrinmethod, this technique made it simple to create Au-NPs with regulated size and low dispersion that are thermally and air-stable. In this method, $AuCl_4$ was present in dodecanethiol and the addition of the reducing agentcauses the transition of the organic phase from orange to dark brown[61-64]. The electrochemical method can be used to create Multiwalled carbon nanotube surfaces with glassy carbon electrodes are coated in Au-NPs.By electrochemically oxidizing the anode and reducing the cathode in a straightforward two electrode cell, Au-NPs were produced[65-67].In seeding growth method, the buried growth method was used to provide restricted size dispersion.Controlling the particle size of gold nanoparticles is achievable by adjusting the seed to metal salt ratio, which in turn enables the generation of different levels within the 540 nm range.This approach has the benefit of being a simple, efficient, and affordable procedure[68-72]. Furthermore,surfactant-assisted methodhad been employed to create partially functionalized Au-NPs. Various surfactants, including oleylamine, poly (N vinylpyrrolidone), and $AuCl_4$in 1,5-pentanediol, were used in the hot injection approach to create Au-NPs and stabilize the colloidal solution. By reducing Au salt chemically in an organic solvent while also adding a stabilizing agent,Au-NPs were created using this process [73-75].

Moreover, leaf broth was used to explain the creation of pure metallic nanoparticles of Ag and Au by reduction of Ag^+ and Au^{+3} ions.[76,77].As potential environmentally acceptable alternatives to physiochemical approaches, biological methods of nanoparticle synthesis using microorganisms, enzymes, and plants or plant extracts have been proposed [78]. By avoiding the complex process of maintaining cell cultures, using plants to synthesise nanoparticles has an advantage over other biological techniques. Significantly, this method has potential to be appropriately scaled up for the large-scale synthesis of nanoparticles. Another benefit of utilising plant extracts instead of bacteria to create nanoparticles is that they are more stable over a longer period of time[79]. Additionally, fungi are able to manufacture more nanoparticles than bacteria because they can secrete enormous amounts of proteins, which directly help to transform into better nanoparticle productivity [80]. Among chemical, physical, and biological methods of both Ag and Au-NPs synthesis, the biosynthesis method produces more NPs' yield compared to the chemical as well as physical methods. Current research has shown that biologically produced nanoparticles are more pharmacologically active than nanoparticles made by physicochemical synthesis [81].

3. Characterization of Ag and Au nanoparticles using various analytical techniques:

ThepreparedAg- and Au-NPs are typically identified by a variety of analytical approaches, includingscanning electron microscopy (SEM), transmission electron microscopy (TEM), atomic force microscopy (AFM), extended X-ray absorption, energy-dispersive spectroscopy (EDS), fourier transform infrared (FTIR), nanoscale infrared spectroscopy, and dynamic light scattering (DLS) (**Figure 2**). Here, the review succinctly focused on each instrument's essential operation and how it helps in NP’s identification.Firstly,the reviewdiscussed about the UV-Visible spectroscopy, among the most crucial methods for the molecular characterisation of metal NPs.ultraviolet-visible spectrophotometerwas often employed to monitor the production and stability of Au and Ag-NPs as they were created.As the process progressed, the Chloroauric acid ($AuCl_4$) and cell-free extract were used to record the UV-visible spectra. Au-NPs exhibit a peak in the surface plasmon resonance at 540 nm, as can be seen from the spectrum [82,83].The reaction reaches its peak intensity after 48 hours, proving that all of the $AuCl_4$ ions have been completely reduced.Similarly,the synthesis and stability of the Ag-NPs produced by the elimination of Ag+ ions in the cell-free extract were monitored using UV-visible spectroscopy.The 450 nm band in the spectrum, which corresponds to the surface plasmon resonance of the spherical Ag-NPs, indicates that Ag nanoparticle creation occurred in the reaction mixture [84-86].Surface plasmon absorbance bands at 525 nm for Au-NPs and 397 nm for Ag-NPs in aqueous solutions served as proof that the citrate-capped Au-NPs and Ag-NPs had been successfully synthesised[87].The colloidal Au and Ag-NPs distinctive colours were caused by the plasmon absorption. Due to oscillations, incoming light absorbs conduction electrons on nanoparticle surfaces as well as electromagnetic radiation. Distilled water is added to the nanoparticle solution to dilute it, and the absorption maximum is set between 0.5 and 0.7[88].To determine particle size, one can utilisethe maximal plasmon absorption wavelength in a given solution. The spectrum is made up of (max 400 nm) Ag-NPs [88]. Because $HAuCl_4$ and the PA solution don't absorb at this wavelength, the Au-NPs absorbance spectra are detected at around 520 nm.

FTIR measurements in transmission mode with a resolution of 8 cm^{-1} over the course of 100 scans. The simulation results were contrasted with the experimental Au-NPs and Ag-NPsFT-IR data. The matching metal acetates were used as model compounds in the molecular orbitalcomputations [89]. It has been previously found and published which bands in the FT-IR spectrum of manufactured Au-NPs and Ag-NPs indicate the existence of biomolecules on the surface of NPs, such as enzymes and protein molecules[90,91].Sincethe ability of proteins to bind metal is greatest when the carbonyl group is present in amino acid residues and peptides, capped Au,Ag-NPs were created to protect aggregation and stabilise the NPs in the medium. This was demonstrated by an IR spectroscopic investigation[92].On the other hand, the aggregate nanoparticles' crystallite size is assessed by XRD analysis. The tests can be performed using a Philips diffractometer from the 'X' Pert firm that emits nanochromatic Cu KI (=1.54060)radiation. The size is calculated using Scherrer's formula, D=0.86/cos, and the width of the XRD peaks. The products' XRD patterns after using only a small portion of the sample allowed for the measurement and confirmation of the nanoparticle size and structure. Also, the XRD pattern pointed to the three diffraction peaks of Ag-NPs, which corresponded to the (111), (200), and (220) planes (JCPDS No. 040783,) diffractions of face-centered cubic(FCC). The metallic Ag serves as an example of the great pureness of the face centered cubic structure with a=4.065[93].However, the monophasic nature of pure Au with FCC symmetry was identified by the XRD arrangementof as-prepared Au-NPs, which shows three peaks at two values of 38.46, 44.65, and 64.73 and is denoted by the indices (1 1 1), (2 0 0), and (2 2 0), respectively (JCPDS No. 011174). The broad, somewhat intense peaks reveal the nanocrystalline structure of Au powder [94-96].

Transmission electron microscopic (TEM) studies is one of the key techniques used for NPs characterisation.In this method, on the carbon-coated copper grids for the TEM approach, a few prepared NPs were inserted.[97]. The TEM apparatus is used to capture micrographs of a drop of NPs while it is operating at, for instance, 200 kv9 Grid TEM is dry. An ultra-thin specimen is passed through by a stream of photons, which interact with the object as they do so. An image is produced from the interaction of the electrons as they move through the specimen. An imaging equipment is used to enlarge and concentrate the image[97].The photos proved that the scattered condition of Au and Ag-NPs was preceded by the ideal starting materials concentration, volume, optimal pH, and incubation time for each reducing agent.[98]. Scanning electron microscope and

EDX analysis,this method is employed to investigate the dimensions and shape of the NPs. For SEM analysis,using a pipet, a small sample was taken and applied to a stub. The stub is composed of copper and has a diameter of around 1 mm.The stub contains double-sided carbon material attached to one side of it.After the sample is put on the carbon material, the stub is fastened to a holder. Aboutseven products can fit in the holder [99]. Using a high-resolution FE-SEM, the Au and Ag-NPs were further analysed. Many spherical, hexagonal, and cubical nanoparticles are generated as a result of the reduction of Au ions, as shown by scanning electron micrographs of the saponin from T. decandra was reduced with HAuCl4 to produce Au-NPs.These Au-NPs have relative diameters between 37.7 and 79.9 nm revealed that tea polyphenols serve as significant reducing agents [100].SEM images of spherical NPswith sizes ranging from 17.9 nm to 59.6 nm have led scientists to believe that reducing sugars may have played a role in the converting of $AgNO_3$ to Ag-NPs [101].The Hitachi S-3400N FE-Thermal SEM's EDX attachment was used to carry out the EDX analysis.The reduction of chloroaurate ions was investigated in the current work, $(AuCl_4)^-$, led to the formation of nanotriangles. EDX spectroscopy was used to further demonstrate that there are Au atoms present in the Au-NPs.The optical absorption peak, which is typical for Au nanocrystallite absorption caused by surface plasmon resonance, was measured at 2.2 keV. Strong Au atom signals were visible in the current EDX spectroscopy image of T. decandra's Au-NPs at energies of 0.30, 2, 2.2, 2.4, and 9.7 keV [102].

Furthermore, EDX spectroscopy was used to demonstrate the presence of Ag atoms in the Ag-NPs. According to surface plasmon resonance,the optical absorption peak, which is typical for the absorption of Ag nanocrystallite, was observed at 3 keV. Individual, spherical Ag-NPs made from alfalfa in a previous work displayed absorption peaks in the 2.5–4 keV range [102,103].Additionally, DLS technique,NPs zeta potential (ξ) provides a crucial insight into their surface charge and stability. The DLS analysis's calculated negative zeta potential () values for b-Au-NPs and b-Ag-NPs(= 10 to 16 mV) demonstrate the stability of these nanoparticles over an extended period of time in solution. These nanoparticles are more stable and have a higher dispersion due to the solution has a repelling negative-negative force[104,105]. X-ray photoelectron spectroscopy (XPS),atomic compositions determined by XPS were compared to simulations produced by various models using experimentally determined values [106].In addition to helping identify the elements present in the sample and determine their oxidation states, XPS is a significant surface-sensitive analytical technique. The produced Ag nanoparticles revealed368.3 and 374.3 eV are the binding energy peaks,which are equivalent to Ag 3d5/2 and Ag 3d3/2's spin-orbit splitting components, respectively. These binding energy peaks are typical of Ag in the zero-oxidation state. At binding energies of 84.3 and 87.9 eV, two spin-orbit splitting components from the high-resolution narrow scan for Au 4f could be extracted, which may be attributed to Au 4f7/2 and Au 4f5/2, dual spin-orbit splitting modes that are unique to Au in metallic form.There is good consistency between the maximum of the measured binding energy for Ag and Auand earlier literature reports [107-109].

4. **Biological application of Ag and Au-NPs**

The numerous applications of nanoparticles in the pharmaceutical area were discussed (**Figure 3**). The vast applicability of Ag and Au-NPs is owing to the nanoparticle's new features, which aid in applications such as superior catalysis, good biocompatibility, huge surface area, and conductivity. When nanoparticles are coupled within the fusion of Au/NPs and Au-NPs/MPA with biomolecules (mercaptopropionic acid), biosensors with a large linear range between 0.25 mM and 1.25 mM glucose concentration with a detection limit of 0.025 mM are extensively used [110]. The antimicrobial activity of the produced Au-NPs and Ag-NPs was tested against eight different S. aureus, E. faecalis, E. coli, P. aeruginosa, P. vulgaris, B. subtilis, Y. enterocolitica, K. pneumoniae, and C. albicans are among the several bacteria that have been found. The antibacterial activity of Au-NPs and Ag-NPs against Y. enterocolitica, P. vulgaris, E. coli, S. aureus, and S. faecalis was very high. Au-NPs inhibited zones ranging from 8.2 mm to 11.5 mm, whereas Ag equivalents inhibited zones ranging from 7.8 mm to 20.3 mm [111]. The nanoparticles exhibit promising antibacterial efficacy against both test microorganisms.Ag-NPs are more biocidal than Au-NPs [112]. In comparison to the gramme-negative bacterium E. coli, the gramme positive bacterium S. aureus was found to be less susceptible to nanoparticles, which may be connected to variations in the cell wall structure. The simplicity, low toxicity of the chemicals used, and creation of practically tiny NPs with acceptable monodispersity and high pureness of the metal NPs are the benefits of this technique [113-115].

Furthermore, the antibacterial activity of Ag-NPsthe development of pits in the bacterial cell wall was found to be closely related to gram-negative bacteria. As a result, the bacterial membrane developed an accumulation of Ag nanoparticles, which significantly increased permeability and led to cell death.[116].Au reacts more readily with soft bases including sulphur or phosphorus. As a result, Ag-NPs are primarily attracted to DNA molecules that contain phosphorus as well as proteins that include sulphur that are located in membranes or inside of cells [116]. Furthermore, thiol groups in enzymes like NADH dehydrogenases are bound by au ions.disrupting the respiratory chain and allowing active oxygen species to be released, resulting in oxidative stress, substantial cell death as a result of harm to the cell's structure [117].Immobilization and labelling of biomolecules on nanoparticles to produce hybrid molecules has been reported using various methods including specific recognition, covalent coupling, physical adsorption, and electrostatic binding [118].Among other things, Au-NPs are used in protein, nucleic acid, and targeted transport as well as in vivo gene therapy[119].Nanoparticles combined with antibodies directed against certain cancer cell surface receptors are used to specifically engage with malignant cells. Functionalized NPs are employed for aimedcell entrance. It has been demonstrated that Au-NPs stabilised by phthalocyanine are a reliable delivery vehicle for photodynamic therapy [120].To permeate the biological membrane and target the nucleus, functional nanoparticles of Au-NPs with a size of 20 nm were coupled to several cellular targeting peptides. Several nanoparticles have also been used as targeted drug delivery and biomarker agents in cancer detection and treatment. Tumor cells or bacteria can be successfully destroyed by Au-NPs functionalized with specific biomolecules [121].The high surface-to-volume ratio of Au-NPs allows for the transport of a large number of medicament molecules [122].Ag nanoparticle application in drug analysis, the placement of Ag-NPs onto supporting is essential for further research into Ag-NP properties. The incorporation of Ag-NPs into graphene oxidesheets, for example, indicates that the antibacterial effectiveness of Ag-graphene oxide nanohybrids was improved over Ag-NPs alone. On rat skin, the Ag/GO hybrids are non-toxic [123].Additional studies [124] found that Ag/GO nanohybrids have outstanding antibacterial activity.The Butea monosperma (BM) leaf extract exhibits a very small cytotoxic effect, whereas the biosynthesized Au and Ag-NPs do not.

However, the Butea Monosperma (BM)leaf extract aids in the synthesis of b-Au-500 and b-Ag-750, which could be helpful for the delivery of a variety of medications used in the treatment of tumors.methanolic/aqueous B. monosperma flower extractexhibits both cellular immune responsesand anticancer action, according to published literatures [125,126]. Nevertheless, aqueous BM leaf extract cytotoxicity has not been reported.In both the DPPH(2, 2-

diphenyl-1-picrylhydrazyl)and PMA(Phosphomolybdenum assay) assays, the free radicals were decreased by the RECO-GNPs and RECO-SNPs' strong antioxidant properties. The nanoparticle was demonstrated to be cytotoxic to HEP G2 cancer cells using the MTT assay. Gram positive and Gram-negative bacteria (Proteus vulgaris) (Micrococcus luteus) bacteria were both found to be inhibited by GNPs and SNPs, with Gram negative bacteria showing the strongest antibacterial action [127].Botanical materials are a rich source of antioxidants. As a result, nanoparticles made from plant sources also have antioxidant action. When compared to nanoparticles created using chemical methods, those created using green methodology had stronger antioxidant capacities. Antioxidant activity of plant-mediated produced Ag/Au nanoparticles has been established [128].An essential part of the inflammatory process is wound healing, which requires the cooperation of vascular and immune cells to restore tissue integrity [129,130].For instance, it was discovered that an ointment combining Falcaria vulgaris and Au nanoparticles facilitated fibroblast migration and accelerated wound healing [131]. Dermal wound healing was accelerated by Au-NPs created using an extract from Gundelia tournefortii L. leaves [132].In a different work, Ag nanoparticles were produced on a “hydroxyapatite” surface to modify the surface and enhance “hydroxyapatite”adherence. The nanoparticles were stabilised and reduced using polydopamine [133].The flower extract of Bauhinia acuminate was used by others as a reducing and stabilising agent while creating Ag nanoparticles. Mesenchymal stem cell proliferation and osteogenic differentiation were increased by Ag NPs, which aided in the treatment of bone fractures [134].In order to transfer experimental drugs and genes to a human fibrosarcoma cell line, biocomposites containing Au-NPs made from plant extracts have been used [135].

5. Conclusion

In conclusion, the preparation of Ag-NPs and Au-NPshad been the subject of extensive research due to their special qualities and the potential for many other uses.Various synthesis methods have been developed, including chemical reduction, green synthesis, and biological synthesis.

Each method had its advantages and disadvantages in terms of efficiency, cost, and environmental impact. Ag-NPshave antibacterial properties, making them effective against a broad spectrum of bacteria. They are also biocompatible and can be used as efficient catalysts. However, the release of Ag-NPs into the environment can have a harmful impact on aquatic organisms, and high doses of Ag nanoparticles can be toxic to living cells.Au-NPsarebiocompatible and exhibit unique optical properties that make them useful in biomedical imaging and sensing applications. They can also be functionalized with drugs for targeted drug delivery. However, Au nanoparticles are more expensive than other metal nanoparticles, and their production process and potential release into the environment can have an impact. Au nanoparticles can also be unstable in certain conditions, limiting their use in some applications.

However, although Au and Ag nanoparticles have promising potential in areas such as medical and environmental applications, it is important to carefully consider the potential impact on the environment and the safety of human exposure. Further research is needed to fully understand the implications of using these nanoparticles and to develop sustainable and safe synthesis methods.

Traditional approaches (physical and chemical procedures) for the creation of nanoparticles call for hazardous substances that have negative side effects. Biosynthesis, on the other hand, results in nanoparticles with more clearly defined sizes and morphologies.Humans also benefit from biosynthetic routes in other ways, such as lowering the use of organic solvent-free media, the consumption of hazardous materials and waste, the formation of waste, the use of ambient temperature and pressure for synthesis to considerably reduce energy consumption,and providing inexpensive, one-step, eco-friendly processes and higher efficiency.Using plants to create biogenic synthesis coulduse to create non-spherical metallic nanostructures with regulated forms and sizes that may be less harmful than those created using standard chemical solvents.Depending on the inorganic materialnano compounds and the type of plant medium utilized (extract vs solution),Moreover, the presence of biologically efficient compounds such as amino acids, proteins, flavonoids, and carboxylic acids gives biosynthesized metal nanoparticles stronger antioxidant capabilities than those made by conventional methods.

Overall, the potential future applications of Ag and Au nanoparticles are vast and diverse. As research continues, new applications and uses for these nanoparticles are likely to emerge, making them an important and versatile area of study. However, it is important to carefully consider the potential environmental and health impacts of their use, and to develop safe and sustainable production methods.

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Conflict of interest:

The authors declare that there is no conflict of interest in the review.

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Figure 1

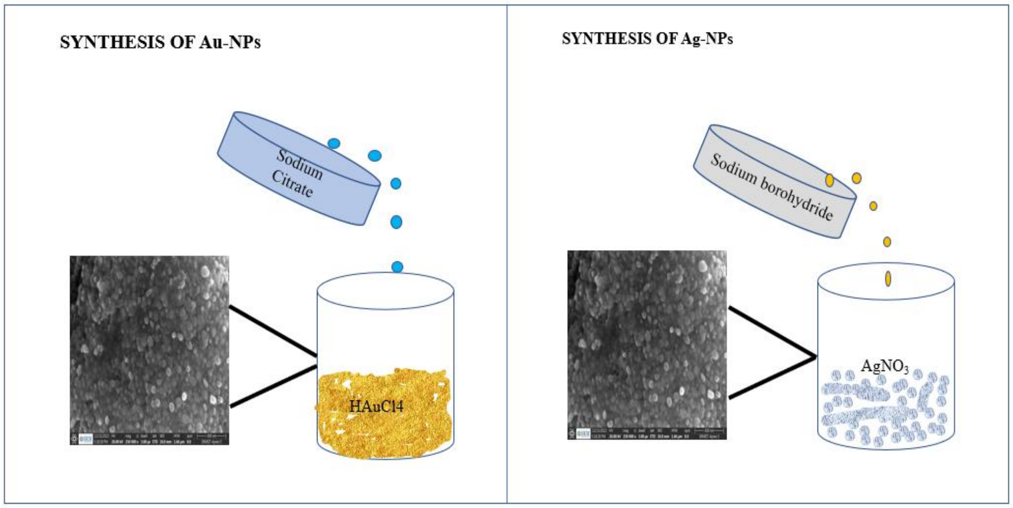

Figure 1. The synthesis of Au-NPs and Ag-NPs typically involves reducing metal salts in the presence of a reducing agent. The reducing agent helps to convert the metal ions into nanoparticles.

Figure 2

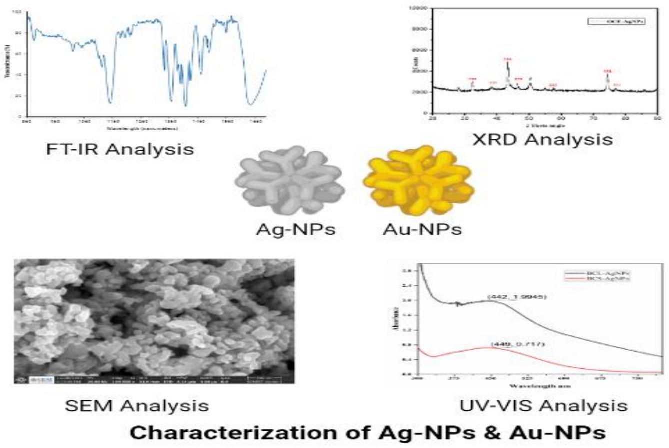

Figure 2. The synthesis of Au-NPs and Ag-NPs mainly conformed this instrumental analysis like FT-IR, XRD, SEM, and UV-VIS analysis.

Figure 3

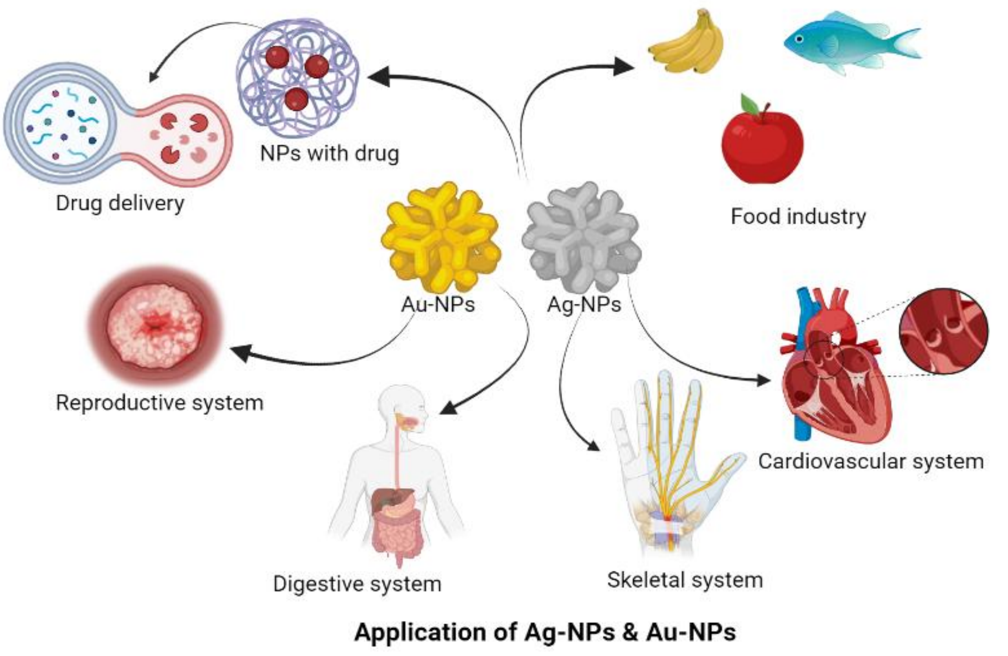

Figure3. Au-NPs and Ag-NPs were used for many applications such as food industry, drug delivery, reproductive system, digestive system, skeletal system, cardiovascular system and many more.