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Gold Nanoparticles in Biotechnology

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ABSTRACT

This article highlights synthesis methods like chemical and green synthesis and the potential application of AuNPs in various fields of biology. Moreover, it also elaborates on the future perspective and challenges and how these solutions to these problems can revolutionize the world of medical sciences. Gold nanoparticles (AuNPs) due to nano sizes have gained significant heed in biotechnology, because of their physicochemical features such as inert, biocompatibility, simple methods of preparation, and unique surface chemistry like surface area, particle size, etc. These features enable AuNPs to fit a broad range of biotechnological and biomedical applications.

Keywords: Gold Nanoparticle, Biotechnology, Application

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Introduction

Nanoparticles are nanosized particles ranging in size from 1-100 nm and have diverse applications in various fields of life. There are numerous nanoparticles and AuNP is one of them. AuNPs possess a broad range of properties such as chemical, optical, and electronic which make them indispensable tools in numerous fields like industrial, scientific, and particularly in biotechnology [1]. The properties, such as the power to undergo surface changes, smooth functionalization, and biocompatibility, make them suitable for biomedical applications. In recent years, AuNPs have been explored deeply for their ability in biosensing, drug delivery, cancer therapy, and imaging. It is inert, less reactive, and non-toxic, allowing it to react with biological materials minimally, rendering it a better material for biotechnological and medicinal fields. Moreover, AuNPs in combination with other biological materials which are nucleic acids, proteins, and peptides, are used for targeted drug delivery and diagnostic procedures. This article will explore the properties and synthesis of AuNPs and their use in biotechnology and future perspectives.

Manufacturing Methods

There are various methods of synthesis, which have their advantages and disadvantages. This step is very important because each method applied can change the properties of nanoparticles including shape, size, functionality, and stability.

Green Synthesis

In this method, environmental and naturally friendly reagents like microorganisms, plant extracts, and other natural compounds are used [2]. These agents behave as reducing agents and are a good alternative to chemical-reducing agents. This method has large-scale implications.

Laser Ablation

In this method, laser irradiation is used to get a large volume of Au from an organic solvent. Laser energy breaks the Au into AuNPs. Obtained AuNPs are mono-dispersed and of high quality. This method is expensive and has not been practiced on a large scale [3].

Chemical Reduction

This is the common method used for the synthesis of nanoparticles. Reducing agents like sodium borohydride, sodium citrate, and ascorbic acid are used to reduce gold salt, particularly gold nitrate or gold chloride [4]. As a result of the reduction, we get AuNPs, the properties of which can be adjusted by the amount of reducing agent and precursor of gold.

Functions

Self-Assembled Monolayers

In this process, the AuNPs are functionalized by reacting with thiol-terminated compounds, for example, thiol-modified DNA or alkanethiols [5]. Reproducible and stable monolayers of AuNPs are formed for biotechnological procedures.

Ligand Exchange

In the ligand exchange method, stabilizing agents are displaced by biomolecules like DNA, RNA, peptides, amino acids, or antibodies. These biomolecules enable AuNPs to specifically bind to targeted cells or tissues [6]. It is a commonly employed method because it provides tailored properties to AuNPs.

Applications in Biotechnology

Drug Delivery

AuNPs can take various therapeutic agents like drugs, nucleic acids, and proteins, and release them. When AuNPs are treated with ligands, bind to specific receptors overexpressed on the target cells' surface. This ensures targeted delivery of the drug, preventing healthy tissues from getting damaged [7]. For instance, when AuNPs are combined with folate receptors, they will target only folate receptors overexpressed in cancer cells, indicating targeted delivery of the drug. AuNPs help in the controlled release of a drug based on external stimuli like light, pH, and temperature. pH-sensitive polymers are used to modify the gold core, allowing secretion of encapsulated drugs in acidic pH, like those present in endosomes or tumor tissues.

Imaging and Diagnostics

AuNPs possess special surface plasmon resonance, which causes marked scattering and absorption of light, a crucial parameter for diagnostics and imaging practices. In a technique, Surface Enhanced Raman Spectroscopy, AuNPs are used to detect small values of biomolecules that help in clinical diagnosis. AuNPs amplify the Raman signal of the required analyte and give rise to rapid results. AuNPs are also employed in the construction of biosensors, for identifying toxins and various pathogens [8]. The optical properties of AuNPs function as sensors in colorimetric assays. For instance, if a specific biomarker is present in the sample, the color of AuNPs will change and demonstrate rapid results.

Cancer Therapy

Nowadays, AuNPs are also used in treating cancer through phototherapy. AuNPs when hit by near-infrared light, take up light and convert it into heat, producing hyperthermia at that site and disruption of cancer cells [9]. This method is non-invasive and provides targeted treatment with minimum harm to the nearby cells.

Future Challenges

For successful applications of AuNPs, various challenges should be addressed. Detailed studies to explore potential toxicities are required for the powerful use in therapeutic medicine. Long-term safety, efficacy, and stability must be thoroughly addressed, before being adopted in clinical practices. Methods for large-scale application of AuNPs are identified to make it cost-effective and for extensive research in biotechnology.

Conclusion

AuNPs are potential tools in the biotechnology field, for wide-ranging applications in the delivery of drugs, diagnostics and imaging, and cancer therapy. Unique physicochemical possessions, like inert, biocompatibility, less toxic, and ease of operation, make suitable candidates for various biomedical applications. Therefore, for broad-scale applications, they are first studied completely particularly their potential toxicities to avoid harmful effects is necessary. Future studies will likely unlock their true potential and optimize the designs for their gross applications. As challenges are solved, AuNPs can revolutionize the field of diagnostics, medicine, and therapeutics.

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