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The Effects of Using Nano Gold on Blood Cells

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Abstract

Many researchers have used gold nanoparticles to treat blood cells because of their positive effects on cells for their ability to reach the target cells inside the body, without being destroyed by the immune system as an intruder. Where Gold nanoparticles (AuNPs) are important components of biomedical applications. Where AuNPs have been used extensively in diagnostics, and are increasingly used in therapeutics. Where the researchers revealed that the gold particles coated with the polymer were the best in terms of the body's immune response, while the gold cells formed in the form of rods were the worst because they reduced the immune response, and the researchers attributed to its heavyweight, andit enters into the body's cells.

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Introduction

Nanotechnology is at the forefront of the most important and exciting fields in physics, chemistry, biology, engineering, and many other fields. The widespread interest in nanotechnology goes back to the period between 1996 and 1998 when the American Global Technology Assessment Center (WTEC) conducted an evaluation study of nanoscale research and its importance in technical innovation. The study concluded that nanotechnology has a great future in all medical, military, informatics, electronic, computer, petrochemical, agricultural, and biological fields, among others, and that nanotechnology has multiple backgrounds as it depends on the principles of physics, chemistry, electrical and chemical engineering, and others. The concept of nanotechnology is based on the assumption that particles whose (a nanometer is a part of a thousand millionth of a meter) give the material that is included in its compositionnew properties and behaviors [1]. This is because these particles (which are smaller than the characteristic lengths associated with some phenomena) introduce new physical and chemical concepts, leading to new behavior based on particle size. It has been observed, for example, that the electronic structure, conductivity, reactivity, melting point, and mechanical properties of matter all change when the particle size falls below a critical value of volume, as the closer the size of matter to atomic dimensions, the more the matter is subject to the laws of quantum mechanics instead of the traditional laws of physics. The dependence of its properties, and accordingly the researchers concluded that this concept has great technical implications that include wide and varied technical fields that include the production of light and strong materials, the reduction of the time of delivery of the Nano medicine to the human circulatory system, the increase in the volume of magnetic tapes and the manufacture Fast computer keys, etc. In general, nanotechnology is one that deals with multiple combinations of materials with dimensions of the order of nanometer[2]. Although nanotechnology is relatively new, the existence of devices that work with this concept and structures of nanoscale dimensions is not new, and in fact their existence dates back to the age of the Earth and the beginning of in vivo manufacture some very small devices that They reach the limits of the nanoscale, as living cells are an important example of natural nanotechnology, where the cell is a repository for a large number of biological machines of the size of nanoscale, and the proteins within them nanotechnology is relatively new, the existence of devices that work with this concept and structures of nanoscale dimensions is not new, and in fact, their existence dates back tothe age of the Earth and the beginning of in vivo manufacture some very small devices that They reach the limits of the nanoscale, as living cells are an important example of natural nanotechnology, where the cell is a repository for a large number of biological machines of the size of nanoscale, and the proteins within them are manufactured in the form of nanoscale combined lines called liposomes, then they are formed by another nanoscale device called Golgi. The enzymes themselves are a nanoscale machine that separates or combines particles according to the need of the cell, and thus the manufactured nanomachines can interact with them and perform the desired goal such as analyzing the contents of the cell, delivering the drug to it, or destroying it when it becomes harmful [3]. Nanomedicine is the application of nanotechnological systems to medicine. The impact of this technology has augmented dramatically over the last few years due to its applications (drug delivery, prevention of drug metabolisation, diagnostic agent, etc.). Thanks to its advantages, to date several nanometric systems have been approved for human use, and more than 240 are in different clinical trial phases. This situation creates the need to implement a wider range of methodological tools to optimize the designof new nanomaterials in early stages of their development and to assess their effect during clinical trials. Blood is one of the first environments that comes into contact with a nanomedicine when it is injected or when it enters the bloodstream via other administration types, which makes the study of the interaction of nanoparticles with different blood components highly relevant.Comprehensive studies have been reported on the effect of nanomaterials on both the immune and coagulating systems. They include the analysis of the impact of these compounds on the morphology, cell cycle and proliferation of different types of blood cells. Indeed, new nanomaterials are designed to make this interaction as controlled and advantageous as possible, and blood cells have even been employed as carrier cells for nanoparticles to reachtheir destiny more efficiently[4]. In (2020) S.S. et al., they studied the excellent properties and advantages of gold nanoparticles copyright by a number of publisher roles. There are different possible physical, chemical, and biological methods in the preparation of colloidal or suspended nanoparticles with pharmacodynamics and optical properties. The surface of the gold nanoparticles plays a role active role in improving performance and effectiveness as carrier nanoparticles of many drugs, especially in the field of cancer therapy. Despite the difficult challenges gold nanoparticles face In drug delivery, these molecules are a great opportunity like Treatment and transporter nano to deliver anticancer drugs and antibiotics vaccine and genetics [5]. In (2019) M.G. et al., the study indicates that the activity of inhibiting and activating immune cells, in some cases, overlap. One of the most common side effects of gold used is sensitivity. Gold relieves rheumatoid arthritis by binding to specific proteins in immune cells and interfering with the production of inflammatory chemical mediators. However, when gold binds to these proteins, it changes its shape. This makes the human immune system recognize these proteins as foreign bodies. The body then begins to attack it; This results in an allergic reaction, and in some cases, this reaction may notoccur to gold, except after a long period of use that may reach months. An allergic reaction to gold appears in the form of rashes and itching, in addition to the damage to the bone marrow, which is an important side effect, it can lead to bleeding problems, anemia, and inflammatory events. This results from damage to the bone marrow, which is responsible for producing various blood elements, including red and white blood cells and platelets. In addition, the deficiency of various blood elements resulting from damage to the bone marrow is not satisfied with causing local damage in a specific place in the body.Rather, it spreads throughout the body, causing many problems [6].

- In (2014) N. L et al., they studied and focused mainly on the synthesis and applications of gold nanoparticles in this field targeted medicines and medication delivery. Nanotechnology has become one of the interesting technologies. Areas of advanced research in this field. Among the nanoparticles, special gold nanoparticles appear. The advantages in this area are due to their unique properties, small size, and high surface area to volume ratio. These particles have been widely used in many biomedical applications and drug delivery systems Because of their inert nature, stability, high dispersion, cytotoxicity, and biocompatibility [7].

- In (2017) M. H. et al., study the effect of various stabilizing agents such as polyethyleneimine (PEI) and polyvinylpyrrolidone (PVP), on gold nanoparticles (AuNPs) and their effect on the activation of equine platelets and the release of specific growth factors. Gold nanoparticles were produced by chemical reduction of chloric acid. UV / VIS spectroscopy confirmed the presence of gold nanoparticles in the analyzed solutions. AuNPs were incubated with whole blood at different concentrations. The platelet morphology of PRP prepared from blood incubated with AuNPs was described by scanning transmission electron microscopy, while the concentrations of growth factors and cytokines were assessed by ELISA assays. The most promising results were obtained with equine platelets incubated with 5% of stabilized AuNPs by PEI, leading to secretion of bone-forming protein 2 (BMP-2), vascular endothelial growth factor (VEGF), and fibroblast growth factor 1 (FGF-1). And at the same time caused a decrease in the concentration of interleukin-1 alpha (IL-1α). QRT- PCR confirmed the results of the ELISA test. Incubation containing 5% of stabilized AuNPs by PEI upregulated BMP-2 and VEGF transcription of mRNA level and reduced the downregulation of expression of interleukin-6 (IL-6). The obtained data shed promising light on the application of gold nanoparticles to the application of regenerative medicine in the future[8].
- In (2017) M.P. et al., Studied human peripheral blood cells are relevant ex vivo models for the characterization of diseases and evaluation of pharmacological effects of therapeutic interventions, as they provide a close reflection of the individual pathophysiological state. In this work, a novel approach is presented to assess the effect of nanoparticles on the three major fractions of human peripheral blood cells by NMR spectroscopy. Thus, a comprehensive protocol was developed that includes separating blood cells, processing them inthe laboratory with nanoparticles, extracting the metabolites, and

characterizing them with NMR. This method was applied to evaluate the effect of gold nanoparticles, either coated with chitosan or fortified with ceria, on peripheral blood cells from healthy individuals. A pronounced antioxidant effect was observed in chitosan-coated gold nanoparticles through a significant increase in the decrease in glutathione, which was less pronounced for the gold-cerium nanoparticles. In addition, the analysis revealed important changes in several other pathways, which were stronger for the gold and cerium nanoparticles. These results are consistent with previously reported toxicological data for these substances, confirming the value of the current methodology[4].

- In(2018) G.G et al., Scientists studied biomedicine, it can be nanomaterials It is used as a tool for early diagnosis and an innovative method of drug delivery. Novel Nanomaterials are currently being manipulated on a large scale without fully assessing their potential Health risks. It is common for nanomaterials to be the first contact with an organism through the various components of the immune system. However, if the entry road is In a vein, the first contact is with blood components (erythrocytes, platelets, White cells, plasma, and complement proteins). The presence of nanomaterials inside a dynamic environment such as the bloodstream can yet produce potentially harmful effects[9].

- In (2016) D. P. et al., Red blood cells (RBCs) can be used for vascular delivery of encapsulated or surface-bound drugs and carriers. Coupling to RBC prolongs circulation of nanoparticles (NP, 200 nm spheres, a conventional model of polymeric drug delivery carrier) enabling their transfer to the pulmonary vasculature without provoking overt RBC elimination. However, little is known about more subtle and potentially harmful effects of drugs and drug carriers on RBCs. Here we devised high-throughput in vitro assays to determine the sensitivity of loaded RBCs to osmotic stress and other damaging insults that they may encounter in vivo (e.g. mechanical, oxidative and complement insults). Sensitivity of these tests is inversely proportional to RBC concentration in suspension and our results suggest that mouse RBCs are more sensitive to damagingfactors than human RBCs. Loading RBCs by NP at 1:50 ratio did not affect RBCs, while 10-50 fold higher NP load accentuated RBC damage by mechanical, osmotic and oxidative stress. This extensive loading of RBC by NP also leads to RBCs agglutination in buffer; however, addition of albumin diminished this effect. These results provide a template for analyses of the effects of diverse cargoes loaded on carrier RBCs and indicate that: i) RBCs can tolerate carriage of NP at doses providing loading of millions of nanoparticles per microliter of blood; ii) tests using protein-free buffers and mouse RBCs may overestimate adversity that may be encountered in humans[10].

- In (2018)H.S. et al., have studied cell death as critical to human health and have to do with various serious diseases. So, a generation of new cell death regulators is urgently needed to treat disease. Nanoparticles (NPs) are now routinely used in a variety of fields, including consumer products and pharmaceuticals. Show stability and ease of patterning, gold nanoparticles (GNPs) can be used in diagnosis and disease. Therapy upon entering the human body, GNPs communicate with human cells in the blood, targeting the organs and the immune system. This property leads to disruption of cell function and even cell death. Therefore, GNPs may act as a powerful regulator of cell death. However, for the time being, the size, shape, and surface of the GNP properties have been observed to play major roles in regulating

the various cell death and related modalities Signal paths. These results may guide the design of GNPs for nanomedicine [11].

- In (2011) S.C. et al., has studied the effect of inorganic nanoparticles on cell growth and the units of the two. This studied aims to find out the effect of iron oxide (Fe_3O_4) and gold (Au) nanoparticles on the cellular growth of E. coli and also try to guide the result obtained by activating partial particles from applications. Fe_3O_4 and Au nanoparticles were prepared and characterized using transmission electron microscopy (TEM) and dynamic light scattering (DLS). Preliminary analysis data indicate that iron oxide nanoparticles have a concentration-dependent inhibitory effect on Escherichia coli, whereas gold nanoparticles did not directly exhibit such activity. The results of the microscopic study of clear phase-contrast showed thatthe effect of both Fe_3O_4 and Au nanoparticles extended to the level of cell division which was evident as a sudden increase in bacterial cell length. The incorporation of nanoparticles by the gold bacterial cell was also observed during the microscopic analysis based on glutathione preparation of gold nanoparticles combining as a vector for transporting plasmid DNA inside the bacterial cell. The study indicates that the study refers to metallic and bacterial nanoparticles at the natural and barbary level, and can also benefit from the formation also in the form of a great ability to produce environmental toxicity, which led naturally to print nanoparticles[12].

- In(2019)J.R. et. al., studied human peripheral blood cells are relevant ex vivo models for characterizing diseases and evaluating the pharmacological effects of therapeutic interventions, as they provide aclose reflection of an individual pathophysiological state. In this work, a new approach to evaluate the impact of nanoparticles on the three main fractions of human peripheral blood cells by nuclear magnetic

resonance spectroscopy is shown. Thus, a comprehensive protocol has been set up including the separation of blood cells, they are in vitro treatment with nanoparticles, and the extraction and characterizationof metabolites by nuclear magnetic resonance. This method was applied to assess the effect of gold nanoparticles, either coated with chitosan or supported on ceria, on peripheral blood cells from healthy individuals. A clear antioxidant effect was observed for chitosan-coated gold nanoparticles by a significant increase in reduced glutathione, which was much less pronounced for gold-cerium nanoparticles. In addition, the analysis revealed significant alterations of several other pathways, which were stronger for gold-cerium nanoparticles. These results are in accordance with the toxicological data previously reported for these materials, confirming the value of the current methodology[13].

1.2 The Aim

Using gold nanoparticles to treat blood cells is a foolproof method that does not lead to cell damage, unlike the traditional methods that cause many damages like leads to increased hemolysis, activation of platelets and leukocytes, cellular damage, and various other negative effects that reduce the quality and efficacy of cellular blood products.

1.3 Research problem

People may be affected by many different types of blood conditions and blood cancers. Common blood disorders include anemia, bleeding disorders such as hemophilia, blood clots, and blood cancers such as leukemia, lymphoma, and myeloma. Therefore, gold nanoparticles were used in the treatment of these cells due to the many properties of gold nanoparticles, oneof the most important of them low toxicity.

Gold nanoparticles one of the most useful nanoparticles in industry and medicine gold nanoparticles are synthesized by many methods like laser ablation. Nanoparticles are described by: electrical resistance spectroscopy(eis), surface plasmon resonance (spr), periodic voltmeter measurement. Conductivity measurement in recent years, gold nanoparticles have been used as chemical sensors. The use of unmodified gold nanoparticles was in color detection mentioned on gold nanoparticles have found applications in treating cancer besides gold in cancer treatment. Nanoparticles were developed in other fields of medicine and biology[14]. Gold nanoparticles are widely used as catalysts for medical therapy, gene therapy, diagnostic and biological purposes. Gold nanoparticles (GNPs) can be applied in diagnostic imaging drugs Delivery radiation sensitivity and phototherapyFor drug delivery, gross national product. It was used as a compatible vector for drug delivery and link targeting. For radiosensitivity and For the purposes of photothermal therapy, biocompatible GNPs can kill cancer cells under external stimuli. Therefore, in most cases, the GNP appears to only function as a "consignment" and "aid" in the biomedical fields. However, Since GNPs can also act as a regulator of cell death, they may treat diseases synergistically[15]. Current nanotechnology plays a pivotal role in a variety of fields and has enabled significant advances to be made in a relativelyshort time. In biomedicine, nanomaterials can be used as a tool for early diagnosis and an innovative method for drug delivery. As nanomaterials research grows, so does increase occupational exposure and very potential environmental pollution due to lack of handling regulations. Studies of nanomaterials began fifteen years ago, and knowledge of their toxic potential is still limited and without appropriate regulatory measures taken.

Toxicologists, epidemiologists, and sociologists, in particular, have discussed the future implications of nanotechnology as well as concerns regarding its toxicity and potential environmental impact. The application of nanomaterials has expanded across a variety of fields, and the lack of attention involved in their regulation is of concern. New nanomaterials are currently being tampered with on a large scale without fully assessing their potential health risks, while commercially available nanomaterials do not actually contain safety data sheets. There is an urgent need for studies that would aid in identifying, understanding, and predicting the cellular or tissue responses that nanomaterials could evoke in humans: it is important tounderstand their safety and put in place protective measures of their own. The potential medical applications of nanomaterials are widespread in the fields of nanoscale imaging, therapy, and diagnostics regardless of the medical use given. Nanomaterials come into contact with human tissues and cells that can lead to reactions that may include blood interactions with nanomaterials, spoilage, acute inflammation, and chronic inflammation [16].

Blood disorders can affect any of the three main components of blood:

- Red blood cells, which carry oxygen to the body's tissues
- White blood cells, which fight infections

- Platelets, which help blood to clot
- Blood disorders can also affect the liquid portion of blood, calledplasma.

Treatments and prognosis for blood diseases vary, depending on the bloodcondition and its severity.

2.2 The main advantage of gold NPs

It is easy to synthesize by chemical reduction technique and have low toxicity compared to various nanomaterials. Different synthesis techniques have been adopted for different dimensions of nanoparticles and surface activation to improve their applications. The main challenges in developing different strategies are their high purity and low multiple dispersion. In order to control the size and shape of NPs, various reducing agents, stabilizers, solvents, etc[17].

2.3 Properties of gold nanoparticles

Gold nanoparticles are different from their bulk form because bulk gold is yellow solid and it is inert in nature while gold nanoparticles are wine red solution and are reported to be anti-oxidant. Interparticle interactions and assembly of gold nanoparticle networks play a key role in the determination of properties of these nanoparticles. Gold nanoparticles exhibit various sizes ranging from 1 nm to 8 µm and they also exhibit different shapes such as spherical, sub-octahedral, octahedral, decahedral, icosahedral multiple twined, multiple twined, irregular shape, tetrahedral, nano triangles, nanoprisms, hexagonal platelets, and nanorods.

2.4 Applications of gold Nanoparticles

The range of applications for gold nanoparticles is growing rapidly and includes:

1. **Electronics -** Gold nanoparticles are designed for use as conductors from printable inks to electronic chips. As the world of electronics become smaller, nanoparticles are important components in chip design. Nanoscale gold nanoparticles are being used to connect resistors, conductors, and other elements of an electronic chip.
2. **Photodynamic Therapy** - Near-IR absorbing gold nanoparticles (including gold nanoshells and nanorods) produce heat when excited by light at wavelengths from 700 to 800 nm. This enables these nanoparticles to eradicate targeted tumors.When light is applied to a tumor containing gold nanoparticles, the particles rapidly heat up, killing tumor cells in a treatment also known as hyperthermia therapy.
3. **Therapeutic Agent Delivery -** Therapeutic agents can also be coated onto the surface of gold nanoparticles. The large surface area-to- volume ratio of gold nanoparticles enables their surface to be coated with hundreds of molecules (including therapeutics, targeting agents, and anti-fouling polymers).
4. **Sensors -** Gold nanoparticles are used in a variety of sensors. For example, a colorimetric sensor based on gold nanoparticles can identify if foods are suitable for consumption. Other methods, such as surface enhanced Raman spectroscopy, exploit gold nanoparticles as substrates to enable the measurement of vibrational energies of chemical bonds. This strategy could also be used for the detection of proteins, pollutants, and other molecules label-free.
5. **Probes** - Gold nanoparticles also scatter light and can produce anarray of interesting colors under dark-field microscopy. The scattered colors of gold nanoparticles are currently used for biological imaging applications. Also, gold nanoparticles are relatively dense, makingthem useful as probes for transmission electron microscopy.
6. **Diagnostics -** Gold nanoparticles are also used to detect biomarkers inthe diagnosis of heart diseases,

cancers, and infectious agents. They are also common in lateral flow immunoassays, a common household example being the home pregnancy test.

7. **Catalysis -** Gold nanoparticles are used as catalysts in a number of chemical reactions. The surface of a gold nanoparticle can be used for selective oxidation or in certain cases the surface can reduce a reaction (nitrogen oxides). Gold nanoparticles are being developed for fuel cell applications. These technologies would be useful in the automotive and display industry [18].

Gold nanoparticles have unique electric and magnetic properties due to their shape and size so they have been received great attention in research areas especially in the field of biological tagging, chemical and biological sensing, optoelectronics, photothermal therapy, biomedical imaging, DNA labelling, microscopy and photoacoustic imaging,surface-enhanced Raman spectroscopy, tracking and drug delivery, catalysis and cancer therapy. Gold nanoparticles based sensors can detect various metal ions by working on the principle of colour change due to the aggregation of gold nanoparticles. Such types of sensors have been widely used for the detection of copper, mercury lead and arsenic in water[19].

Gold nanoparticles' interaction with light is strongly dictated by their environment, size, and physical dimensions. Oscillating electric fields of a light ray propagating near a colloidal nanoparticle interact with the free electrons causing a concerted oscillation of electron charge that is in resonance with the frequency of visible light. These resonant oscillations are known as surface plasmons. For small (~30nm) monodisperse gold nanoparticles, the surface plasmon resonance phenomenon causes absorptionof light in the blue-green portion of the spectrum (~450 nm) while red light (~700 nm) is reflected, yielding a rich red color. As particle size increases, the wavelength of surface plasmon resonance-related absorption shifts to longer, and redder wavelengths. Red light is `then absorbed and blue light is reflected, yielding solutions with a pale blue or purple color. As particle size

continues to increase toward the bulk limit, surface plasmon resonance wavelengths move into the IR portion of the spectrum and most visible wavelengths are reflected, giving the nanoparticles clear or translucent color. The surface plasmon resonance can be tuned by varying the size or shape of the nanoparticles, leading to particles with tailored optical properties for different applications [18].

2.5 Gold Nanoparticle Synthesis Methods

Gold nanoparticles (AuNPs) are one of the important branches of nanometal research. There are currently more than 1,000 methods available for synthesizing gold nanoparticles. The formation of nanoparticles by decomposition of high-energy radiation or electron bombardment based on transmission electron microscopy is widely known. There are various methods of synthesizing gold nanoparticles, including chemical synthesis, physical synthesis, and biosynthesis. Innovative and environmentallyfriendly nanotechnology-based methods have recently emerged mainly usingbiological resources to produce nanostructures with unique antibacterial properties. Biosynthesized gold nanoparticles using cell-free extract of erythrocyte yeast. For an eco-friendly approach, natural plant extracts contain a variety of metabolites, including carbohydrates, alkaloids, terpenes, phenolic compounds, and enzymes. Biomolecules in plant extracts can reduce metal ions to nanoparticles through a one-step and environmentally friendly synthesis process. Described the plant-mediated synthesis of metal nanostructures (gold and silver) using an ethanol extractof Melissa officinalis L. (obtained by accelerated solvent extraction). In the study, Doan et al. used the water extract of waste corncobs to prepare cost- effective and environmentally friendly silver and gold nanoparticles. The formation of metal nanoparticles (MNP) is optimized by the UV-Vis method. Gold nanoparticles (CC-AuNPs) show high antibacterial activity

against three bacterial strains including Salmonella typhimurium, Bacillus cereus, and Staphylococcus aureus. Gold nanoshells also have interesting physical properties, including optical and surface plasmon resonance, which can be customized during the synthesis process, giving gold nanoshells significant potential in nanomedicine[19].

2.6 Blood Disorders Affecting Red Blood Cells

Blood disorders that affect red blood cells include:

- Anemia.
- Iron-deficiency anemia.
- Anemia of chronic disease.
- Pernicious anemia (B12 deficiency.
- Aplastic anemia.
- Autoimmune hemolytic anemia.
- Thalassemia.
- Sickle cell anemia.
- Polycythemia vera.
- Malaria.

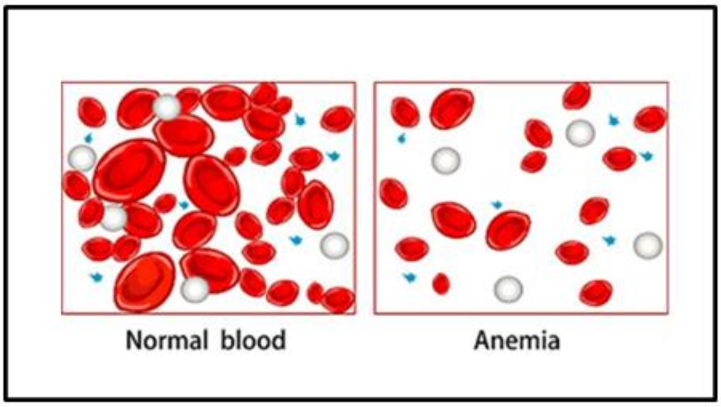

Figure (1): Explains the difference between anemias of normal cells [20].

2.7 Blood Disorders Affecting White Blood Cells

Blood disorders that affect white blood cells include:

- Lymphoma.
- Leukemia.
- Multiple myeloma.
- Myelodysplastic syndrome.

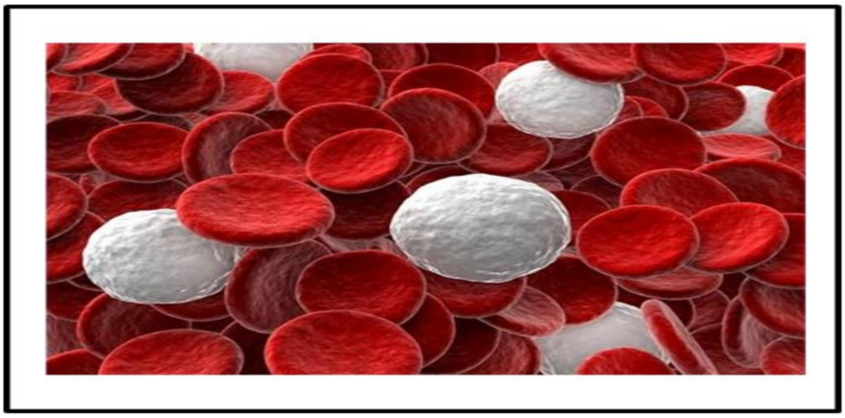

Figure (2): Explains the White Blood Cell [21].

2.8 Blood Disorders Affecting Platelets

Blood disorders that affect the platelets include:

- Thrombocytopenia.
- Idiopathic thrombocytopenic purpura.
- Heparin-induced thrombocytopenia.
- Thrombotic thrombocytopenic purpura.
- Essential thrombocytosis (primary thrombocythemia.

2.9 Blood Disorders Affecting Blood Plasma

Blood disorders that affect blood plasma include:

- Hemophilia.
- Von Willebrand disease.
- Hypercoagulable state (hypercoagulable state.
- Deep venous thrombosis.
- Disseminated intravascular coagulation (DIC)[22].

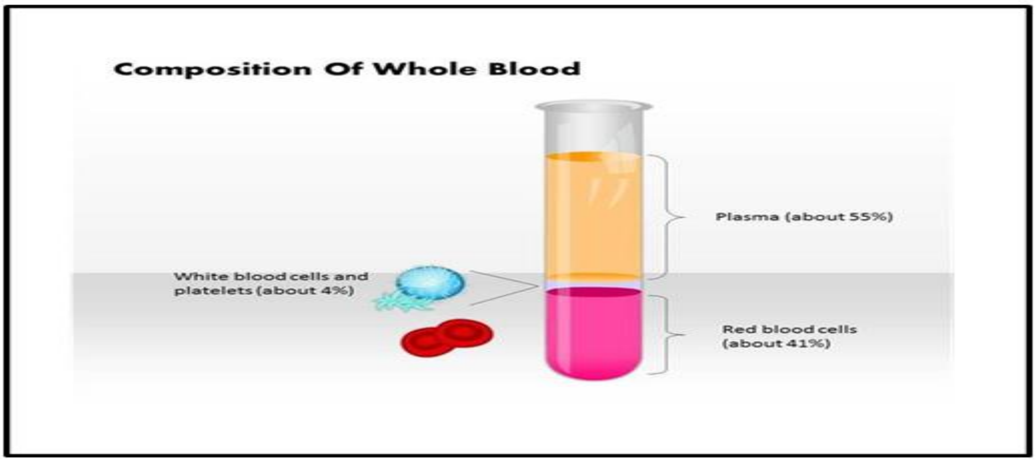

Figure (3): Explains Compsition of Whole Blood [23].

2.3 Conclusion

The benefits in this field are due to their special properties, small scale, and high surface area to volume ratio, which have been found in previous research. Gold nanoparticles have been used in many illnesses, not only in the treatment of blood cells, but also in the delivery of treatment, cancer treatment, and bacteria-killing. Because of their inert composition, mobility, high dispersion, cytotoxicity, and biocompatibility, these particles have beenextensively utilized in several biomedical applications and drug delivery systems.

Novel Nanomaterials are now being manipulated on a wide scale without having their possible health effects thoroughly assessed.

Nanomaterials are always the first thing that an individual comes into contact with through the immune system's different components. If the entrance point is a vein, though, the first touch is with blood products (erythrocytes, platelets, White cells, plasma, and complement proteins). The appearance of nanomaterials in a complex ecosystem like the bloodstream will also have negative consequences.

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