NANOTECHNOLOGY IN PHARMACEUTICAL SCIENCE

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ABSTRACT

One of the most basic unit operations that is crucial to pharmacy is size reduction. It aids in lowering toxicity, increasing release, strengthening stability and bioavailability, and presenting improved chances for drug formulation.

The science of nanotechnology studies processes that take place at the molecular level and at nanoscale sizes. Though it has a significant impact on many medical fields, including biophysics, molecular biology, bioengineering, cardiology, oncology, ophthalmology, endocrinology, immunology, etc., nanotechnology has made enormous strides in physics, electronics, and engineering but has not yet been thoroughly investigated in the biomedical and pharmaceutical domains. Intelligent systems, tools, and materials are made possible by nanotechnology, improving pharmaceutical applications.

KEYWORDS

Pharmaceutical Nanotechnology, Nano scale, Drug delivery, Bio nanotechnology

INTRODUCTION

One of the basic unit operations with significant applications in pharmacy is size reduction. It aids in lowering toxicity, increasing release, increasing solubility and bioavailability, and improving chances for drug formulation. Nanomedicine-sized drugs improve performance across a range of dose forms. Among the main benefits of nanosizing are:

1. A larger surface area

2. Enhanced Absorbance

3. A Higher Dissolution Rate

4. A higher level of oral bioavailability

5. A Faster Commencement of Therapeutic Effect

6. Lower Needed Dose Amount

7. A reduction in the Fed/Fasted Variability

8. Reduced Variability Among Patients.

It is commonly believed that nanotechnology and nanoscience have enormous   potential to advance numerous fields of study and application. When Norio Taniguchi, a physicist at the University of Tokyo in Japan, discussed materials in nanometers.

The term "nanotechnology" was first used in 1974. Any technology with real-world applications at the nanoscale is considered to be part of the multidisciplinary field of nanotechnology. The science of nanotechnology studies the molecular processes that take place at the nanoscale (i.e., 10°)2.

NANODEFINITIONS

The study of phenomena and material manipulation at the atomic and molecular scales is known as "**nanoscience**."

"Design, characterization, production, and applications of structures, devices, and systems through control are associated with **nanotechnology**."

Submicron-sized (<1um) modules that are utilized for biological system monitoring, control, diagnosis, and treatment are referred to as "**nanomedicine**."

Pharmaceutical nanotechnology includes the use of nanoscience in pharmacy to create nanomaterials and technologies such as biosensors, diagnostic imaging, medication delivery, and imaging devices.

The science of measurements at the nanoscale is called **nanometrology**. Four frequently. Transmission electron microscopy (TEM), scanning electron microscopy (SEM), scanning probe techniques (SPM), and optical tweezers (single-beam gradient trap) are among the methods employed.

The study of how nanostructures interact with biological systems is known as **nanotoxicology**, and it focuses on the connection between a nanostructure's chemical and physical characteristics and the creation of a toxic biological response.

Bionanotechnology generally refers to the study of how the goals of nanotechnology can be guided by studying how biological "machines" work and adapting these biological motifs into improving existing nanotechnologies or creating new ones.

A new area of study in nanoscience and biomechanics called **nanobiomechanics**, also known as **bionanomechanics**, uses the potent tools of nanomechanics to investigate the underlying principles of biomaterials and biomechanics. Red blood cells contaminated with, for instance, have been linked to illnesses. It is anticipated that the market will be overrun with medications utilizing nanotechnology within the next ten

years. Pharmaceutical nanotechnology has a very broad application range, ranging from intelligent tools for medication delivery and diagnostics to smart materials for tissue engineering, and more recently, artificial red blood cells, etc. The creation of nanomedicine, tissue engineering, nanorobots, advanced diagnostics, as a carrier of therapeutic and diagnostic modalities, as a biosensor, biomarker, image enhancement device, implant technology, bioactive surfaces, etc. are some of the current uses of nanotechnology in pharmacy.

Fig.1.1 Types of pharmaceutical nanosystem
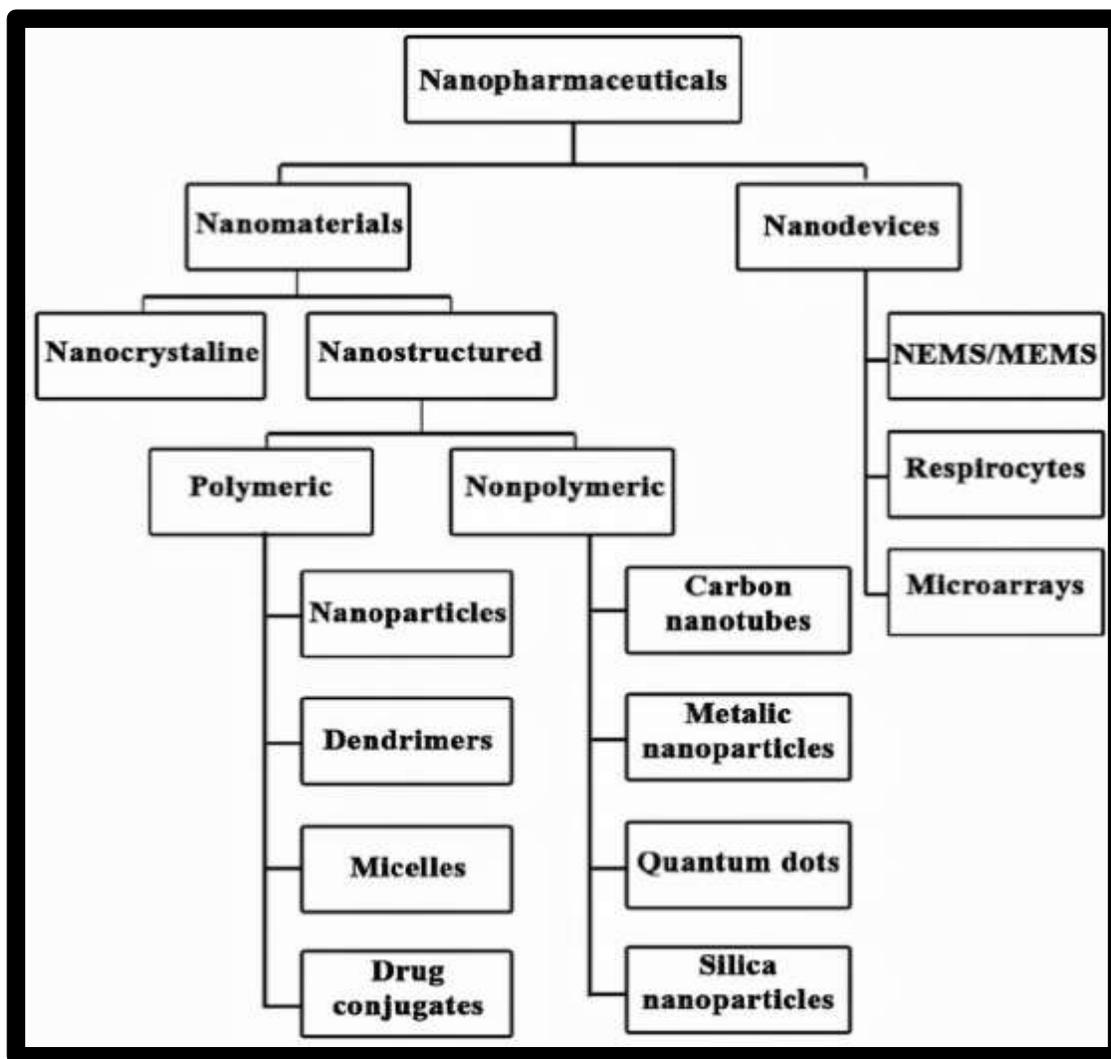
SCOPE AND OPPORTUNITIES

PHARMACEUTICAL NANOTECHNOLOGY BASED SYSTEMS

The two fundamental categories of nanotools that pharmaceutical nanotechnology offers are nanomaterials and nanodevices, and they are essential to the field of pharmaceutical nanotechnology and its allied areas. Biomaterials known as nanomaterials are utilized as scaffolding for tissue-engineered products or as orthopedic or dental implants. By encouraging the interaction of living cells with the biomaterial, its surface changes or coatings may significantly improve the biocompatibility. These substances can be further divided into nanostructural and nanocrystalline substances. Because they are easily produced, nanocrystalline materials are a great replacement for bulk materials that perform worse. Implants, prosthetics, bone replacements, and medication encapsulation can all benefit from the utilization of raw nanomaterials.

Materials with nanostructures. Treated versions of unprocessed nanomaterials, such as quantum dots, dendrimers, and fullerenes, that offer unique shapes or functions.

NANOPARTICULATE DRUG-DELIVERY SYSTEMS

An ideal drug-delivery system owns two elements:

A. The ability to target
B. B. To control the drug release.

Targeting ensures high efficiency of the drug, reduction in the side effects, especially when dealing with drugs that are presumed to kill cancer cells but can also kill healthy cells. When delivered to them. The reduction or prevention of side effects can also be achieved by controlled release of the medicament to the target. Nano particulate provides a better penetration of the particles to the body as their size allows delivery through intravenous injection or other routes.

Lipid-Based Colloidal Nano drug-Delivery Systems

Submicron-sized particles produced by composed of a solid or semisolid shell surrounding an oily liquid center. Shell. The potential uses for colloidal drug carriers are numerous. Benefits as methods of medication delivery. A few benefits are improved oral, cutaneous, and intravenous administration spectrum; utilization of physiological lipids; avoidance of organic solvents during manufacture; and improved bioavailability for poorly soluble medicines. Among the typical drawbacks include particle growth, Because of the solid-liquid nanoparticles' crystalline structure, they have an unpredictable gelating propensity, unanticipated dynamics of polymorphic transitions, and intrinsically limited integration capabilities.

Recent Trends in Solid-Lipid Nanoparticle Research

Lately, a solvent-free lipid-based formulation method has been created to create lipid nanocapsules with dimensions in the nanometer range. This procedure capitalizes on the fluctuations in the hydrophilic-lipophillic equilibrium of an temperature-dependent ethoxylated hydrophilic surfactant, resulting in an inversion phase.

Polymeric Micelles as Drug Carriers Systems

Polymeric micelles have attained attention in drug delivery, partly due to their ability to solubilize hydrophobic molecules, their small particle size, good thermodynamic solution stability, extended release of various drugs, and prevention of rapid clearance by the reticuloendothelial

System (RES). Critical micelle concentration (CMC), similar to low-molecular-weight surfactants, is the key characterization parameter for polymeric micelles. Furthermore, various types of drugs can be loaded into the hydrophobic core of polymeric micelles by chemical conjugation or physical entrapolymeric micelles by utilizing various interactions such as hydrophobic interactions, or ionic interactions, or hydrogen bonding. The hydrophobic core serves as a reservoir from which the drug is released slowly over a longer period of time

POLYMER-BASED NANOPARTICULATE DRUGDELIVERY SYSTEMS

1. Drug Delivery Systems Using Hydrogel-Based Nanoparticulate.
2.   Drug Delivery Systems Based on Dendrimers.
3. Carbonate nanoparticles of calcium.
4. Nanoparticulate Drug Carriers (Proticles) Based on Protamine: With a molecular mass of about 5000 g/mol, protamine is a peptide that is practically harmless and nonantigenic. It is obtained from salmon, which is the most commonly used source of the chemical. It serves as a cationic component and can be employed as a carrier system to carry oligonucleotides or DNA.
5. Nanoparticulate Drug-Delivery System Based on Chitosan: Chitosan, a polycationic polymer of d-glucosamine and N-acetyldglucosamine connected by b-(1, 4)-glycosylated bands, has been extensively employed in NPDDSs to administer vaccinations, genes, and anticancer medications. Biocompatible and a natural polymer is chitosan. Additionally, chitosan nanoparticle uses for the eyes are being investigated.
6. A medication delivery system based on silicone nanopore membranes.
7. Gelatin nanospheres and albumin.
8. Polymeric Nanocapsules as Drug Carriers.
9. Nanospheres made of polystyrene.

TYPES OF PHARMACEUTICAL NANOTOOLS

1.Carbon nanotubes: Carbon nanotubes are made of a layer of graphite rolled up into a cylinder, with a diameter of 1 nm and a length of 1-100 nm. They are hexagonal networks of carbon atoms.
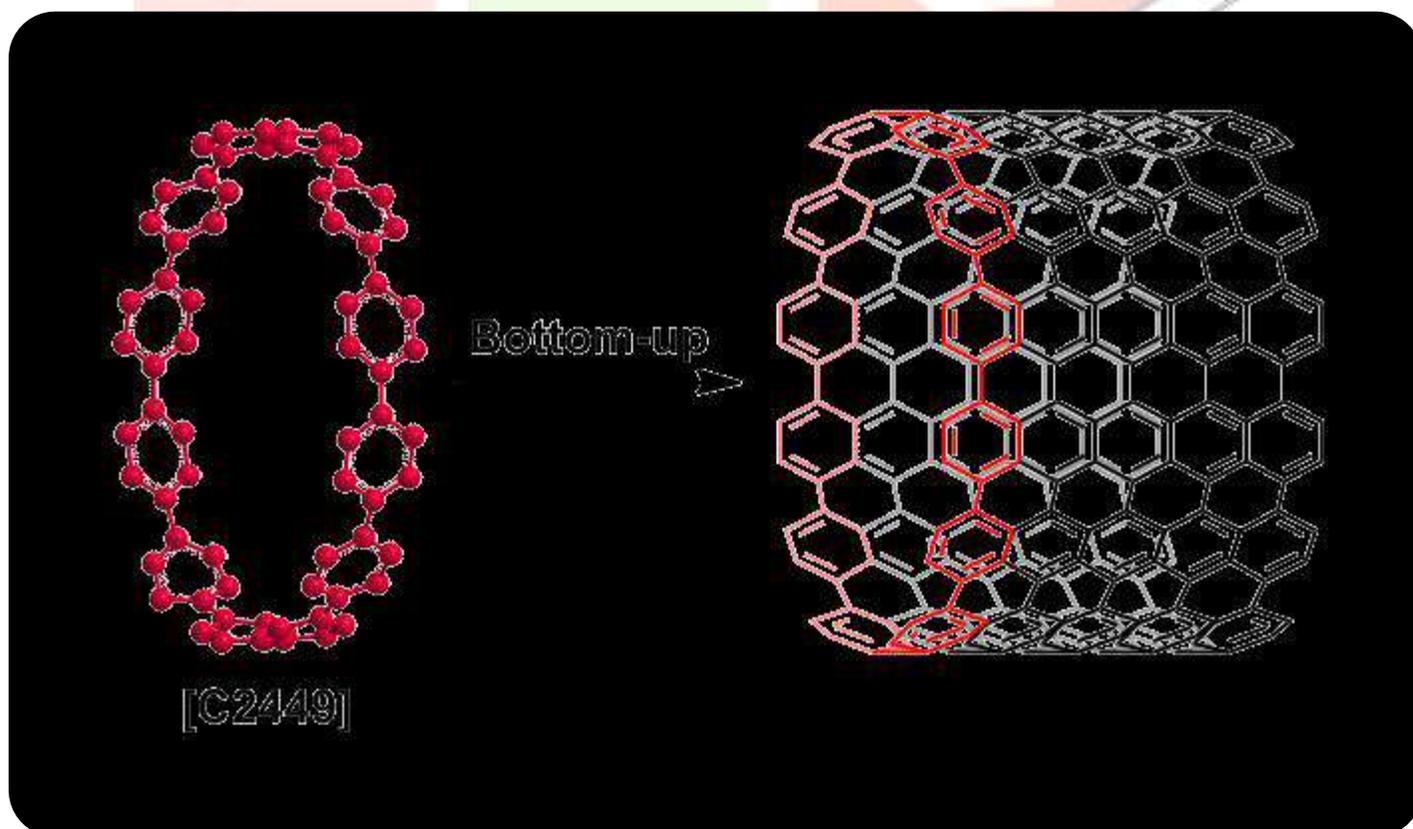

Fig.1.2 Structure of Nano Carbon

Single-walled nanotubes (SWNTs) and multi-walled nanotubes (MWNTs) are two different forms of nanotubes that are distinguished by the way their graphene cylinders are arranged

2.Quantum Dots : Semiconducting materials known as quantum dots (QDs) are composed of a semiconductor core (CdSe), a shell (such as ZnS) to enhance optical characteristics, and a cap to aid in increasing solubility in aqueous buffers. The detection and analysis of biomolecules both in vitro and in vivo, as well as diagnostic techniques such as magnetic resonance imaging (MRI), have all benefited greatly from the discovery of quantum dots.

3.Dendrimers: These are highly branched, tree- like structures and have different compartments of chemical polymer. Dendrimer contain three different regions: core, branches, and surface. They have promising properties for delivery of bioactives ranging from drugs, vaccines, metal, and genes to desired sites. Their hollow interior provides space to incorporate drugs and other bioactive physically or by various interactions. To act as drug delivery vehicles. Most important applications of dendrimers are solubilization, gene therapy, dendrimer based drug delivery, immunoassay and MRI contrast
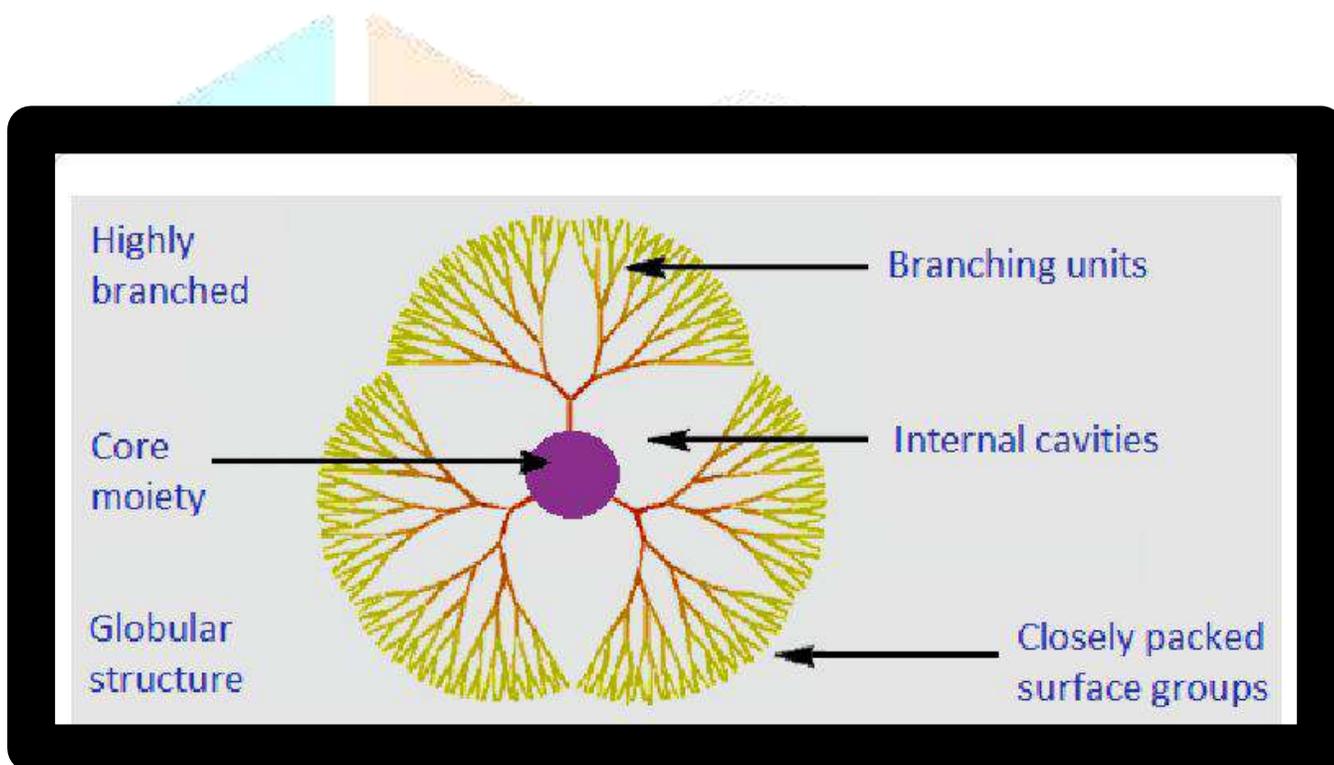
Fig 1.3 schematic representation of dendrimer

4. Liposomes : These are closed vesicles that are formed when dry phospholipids are hydrated.There are three fundamental forms of liposomes. Multilamellar vesicles (MLVS) are characterized by the quantity and size of lipid bilayers that are separated from each other by aqueous gaps. One bilayer encircling the entrapped aqueous area makes up small unilamellar vesicles (SUVs) and large unilamellar vesicles (LUVs).

5.Polymeric Micelles: Polymeric micelles are amphiphilic block copolymers with a supramolecular core-shell structure, often measuring less than 100 nm.

6.Polyplexes/ Lipopolyplexes: These assemblies, which are employed in transfection techniques, spontaneously form between nucleic acids and polycations or cationic liposomes (or polycations coupled to targeting ligands or hydrophilic polymers).

ENGINEERING OF PHARMACEUTICAL NANOSYSTEMS

Nanosystems are not widely recognized for drug biodelivery since they are a chemical entity. To make them suitable for biological transport, they must be modified by adding some site-specific ligands and biocompatible polymers to change their size and surface.

1.Functional Nanosystem: Surface functionalization is the process of modifying the characteristics of nanosystems by incorporating, adsorbing, or covalently attaching substances like ligands or polymers to their surface. Polymers, sugars, endogenous substances/ligands, peptides, proteins, nucleic acids, and polysaccharides are some of the frequently used instruments for surface modification.

2.Multifunctional Nanosystems: Three approaches can be utilized to produce multifunctional nanosystems. First, the material's core is given multifunctionality to enable the simultaneous delivery of two or more therapeutic active moieties; second, the surface is given multifunctionality to stabilize the targeting moiety's circulation time and use; and third, the material is given multifunctionality through the use of biomaterials that are pH, temperature, and stimuli sensitive.

NANOTECHNOLOGY IN DRUG DELIVERY: NANOPARTICLES

The creation of therapeutically effective formulations for patient treatment is the ultimate objective of the application of nano-drug delivery systems. A particular amount of a medicine that can be therapeutically beneficial must be delivered by clinically useful drug delivery systems, frequently over an extended period of time.

The fact that the systems must be inserted into the human body and receive FDA (Food and Drug Administration) approval has also received little attention. Nowadays, the majority of nano/micro particle preparation techniques rely on solvent exchange techniques or double emulsion techniques. 14–15 In order to create drug nanocrystals, nanoparticles, nanoprecipitates, and nanosuspensions—all of which are generally referred to as nanocrystals for simplicity of comprehension—a variety of nano-designing procedures, including milling, high pressure homogenization, controlled precipitation, etc., are being investigated.

In medicine, controlled medication delivery techniques have had a significant impact. Generally speaking, controlled-release polymer systems prolong the time at which a medication is administered at the ideal dosage, improving patient compliance, boosting the effectiveness of the medication, and improving the usage of extremely poisonous, poorly soluble, or relatively unstable medications. Therapeutic and diagnostic techniques that are highly selective and effective can be developed by utilizing nanoscale materials as drug delivery vehicles.

Particulate dispersions or solid particles with a size range of 10 – 1000 nm are referred to as nanoparticles. A nanoparticle matrix is used to dissolve, entrap, encapsulate, or bind the medication. One can obtain nanoparticles, nanospheres, or nanocapsules depending on the preparation technique used. Controlling the size of the particles, their surface characteristics, and the release of pharmacologically active compounds are the main objectives when designing nanoparticles as a delivery system. This allows the medicine to act on specific sites at the ideal pace and dosage.

PREPARATION OF NANOPARTICLES

A.Dispersion of preformed polymers by:

1. Schwant evaporation method.

2. Spontaneous emulsification/solvent diffusion method

3. Salting-out/emulsification diffusion method

4. Production of nanoparticles using superstitical technology

5. Polymenaation methods.

6. NPs prepared from hydrophilic polymers

B.Polymerization of monomers:

A variety of substances, including proteins, polysaccharides, and synthetic polymers, can be used to create nanopartides. The choice of matna materials depends on a number of variables, like as

1. Size of nanopartides required

2. Inherent properties of the drug

3. Surface chanacteristics such charge and permeabilns:

4. Degree of biodegradability, biocompatibility and toxicity

5. Drug releme profile desired

6. Antigenicity of the final product.

Three techniques have been used most frequently to prepare nanoparticles:

(1) Dispersion of preformed polymers,

(2) Polymerization of monomers

(3) gelation or coacervation of hydropulic polymers

APPLICATIONS OF PHARMACEUTICAL NANOTOOLS

Overcoming physiological, binchemical, and pharmacological barriers is aided by ze reduction. Numerous benefits are offered by the large range of nanoscale systems and devices that pharmaceutical nanotechnology offers. A few significant uses for armas are

1.As Nanomaterials for tissue engineering:

Many smart materials, including those for bone replacement, implant coatings, tissue regeneration scaffolds, structural implant materials, and fur tissue repair and replacement, have been made possible by nanotechnology.

2. **Nanobased drug delivery toals:**

These The following can be classified with broodingness: nanoparticles, posome dendrimers, polymeric micelles, polymer-drug conjugates, antibody drug conjugates

1. Sustained and controlled delivery system,
2. Stimuli sensitive delivery system
3. Functional system for delivery of bioactive
4. Multifunctional system for combined
5. Delivery of therapeutics, biosensing and diagnostic
6. Site specific targeting intracellular, caifular, tissue)
7. Furthermore, nanobased drug delivery in the tools now being employed treatment of various diseases such as in cancer Therapy etc

3.Molecutor Diagnostics:

The nanoscience of molecular imaging involves the representation, characterization, and quantification of biological processes occurring under the surface of organisms.

Gene expression, signal transduction, protein-protein interaction, cellular metabolism, and intracellular and intercellular trafficking are examples of processes. Numerous imaging techniques, including magnetic resonance imaging, optical imaging, ultrasonic imaging, and nudear imaging, have been effectively employed with them.

4.Biosensor and Biolabels:

This clever and promising technique has been used to produce a number of analytical tools. These instruments are utilized to identify different pathogenic proteins and physiological-biochemical markers linked to illness metatholic states of the body that are disturbed.

A biological sensor is a broadly defined measurement device comprising three components: a physicochemical detector component, a probe sensitive biological recognition bicreceptor, and a transducer that amplifies and transduces these signals into a form that can be measured.

5.Drug discovery:

Pharmaceutical nanotechnology is essential to the search for new drugs because it helps identify biomarkers linked to certain diseases and improve our understanding of how drugs work. Nanotechnology is beneficial. Dentifying the proteis present on the call surface or target surface allows for the identification and validation of the target. Nanotechnology will improve drug discovery by assaying things faster, more easily, more easily, and more miniature.

CHALLENGES TO PHARMACEUTICAL NANOTECHNOLOGY

Pharmaceutical nanotechnology has made it possible to treat diseases more precisely and with greater precision. Nonetheless, a few moral, scientific, and social and legal concerns providing a number of difficulties for the actual application of pharmaceutical nanotechnology.

Several significant health risks Cytotoxicity, translocation to undesirable cells, acute and chronic toxicity, some unknown, erratic, and unclear safety difficulties, environmental effects of nanomaterials, and non-biccompatibility are all linked to such devices. FDA regulations pertaining to pharmaceutical nanotechnology-related products and concerns are not specifically mandated by the agency. While some FDA-approved goods based on nanotechnology have made their way into the market, they include polymer drug conjugates,

nanoparticles, monoclonal antibody-based products, and polymer-protein conjugate polymeric pharmaceuticals. Similar These issues have created an urgent need to regulate these delivery systems and items that are based on nanotechnology.

FUTURE PROSPECTS OF PHARMACEUTICAL NANOTECHNOLOGY

The developing field of pharmaceutical nanotechnology has the potential to have a significant impact on human health. Nanomaterials are being utilized more and more in tissue engineering and drug delivery applications, with the potential to completely transform medicine. An innovative notion is emerging: a modular method to building delivery systems that integrate medicinal, imaging, and targeting features into nanoplateforms. These multifunctional nanoplateforms would precisely deliver treatments after localizing to specific cells and enabling diagnostics. Incredibly intriguing and innovative future One approach is to design a nanomachine that can simultaneously identify and combat pathogens, identify changes in molecular events that occur during a disease state, and track the effectiveness of treatment. Nevertheless, such a clever device is also aware of nanoroners, which act as miniature onboard.The development of several medicinal techniques and the worldwide interest expressed by governments, businesses, and scientists guarantee that there is enormous potential and reach of nanotechnology medication administration

ACKNOWLEDGEMENT

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