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An Overview of the Role of Nanotechnology in Modern Pharmacy

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ABSTRACT

Numerous newly developed molecular entities (NMEs) are chosen for extensive development based on safety and pharmacological data, but they often exhibit unfavorable physicochemical and biopharmaceutical characteristics. These shortcomings result in suboptimal pharmacokinetics and distribution when administered in vivo. Nanotechnology has made remarkable advancements in addressing these challenges, although its potential in the biomedical and pharmaceutical fields has not been fully explored. Nanotechnology represents an interdisciplinary convergence of fundamental sciences and practical disciplines such as biophysics, molecular biology, and bioengineering. It has significantly impacted various medical domains, including cardiology, ophthalmology, endocrinology, oncology, pulmonology, and immunology, as well as highly specialized areas like gene delivery, brain targeting, tumor targeting, and oral vaccine formulations. When nanoparticles are harnessed as drug delivery systems, they effectively address issues related to poorly water-soluble drug formulations and offer distinct advantages in enhancing drug effectiveness while reducing adverse reactions. The utilization of nanotechnology in disease diagnosis is rapidly evolving, thanks to the unique size-dependent properties of these materials, which make them invaluable across various aspects of human endeavors.

❖ INTRODUCTION:

The exploration and development of new drugs for treating diseases are complex, requiring ongoing dedication to scientific research. Nanotechnology, which involves the molecular-scale design of functional systems, offers unique physical, electrical, and optical properties that make it compelling for applications across various fields, including materials science, medicine, and biology.

Recent studies indicate that the average timeline for discovering, developing, and approving a new drug in the United States is approximately 14.2 years, involving substantial research expenditures, estimated at $800-$900 million in 2003. The utilization of nanotechnology in disease treatment, diagnosis, monitoring, and control is commonly referred to as "nanomedicine."[3] While the use of nanotechnology in medicine might seem like a recent trend, its foundational principles for medical applications date back several decades.

The distinctive attributes and utility of nanoparticles stem from a variety of factors, including their size similarity to biomolecules such as proteins and polynucleic acids, which enhances their effectiveness in various medical contexts.

❖ Why is nanotechnology so important?

The potential of nanotechnology extends to revolutionizing every aspect of our daily lives.

- **Nanotechnology affects all materials:**

Materials like ceramics, metals, polymers, and biomaterials serve as the cornerstone for significant technological progress. Over the next decade, nanotechnology is poised to bring about a substantial impact. [30] These forthcoming advancements have the potential to revolutionize our approaches to manufacturing, electronics, information technology, and communication technology, rendering previous technologies obsolete and paving the way for innovative applications that were previously inconceivable without this novel approach. [4]

❖ Physiologic and Biologic Characteristics of Nanoparticles:

In chemotherapy, the issue lies in the lack of precise targeting and the potential for toxic side effects when delivering cancer drugs to tumor tissue. Conventional drug delivery methods, such as oral and intravenous routes, come with their drawbacks. [5] For instance, oral administration through tablets or capsules can result in unpredictable pharmacokinetics due to exposure to the body's metabolic processes.

Nanoparticle-based drug delivery, incorporating biodegradable polymers, offers a more effective and less harmful solution to address some of these challenges. Notably, in 1975, Ringdorf introduced a groundbreaking concept: a polymer-drug conjugate model aimed at enhancing the delivery of anticancer agents. This innovation marked a significant advancement in drug delivery techniques. [6]

- **Formulation considerations in drug development**

The use of combinatorial chemistry techniques and the exploration of physiologically relevant targets through genomics and proteomics strategies have led to an expansion in the pool of new molecular entities (NMEs) under consideration for development. [7]

- **Nanotechnology in drug development:**

Nanomedicines are essentially drug delivery systems designed to function on a nanoscale, typically less than 500 nanometers, offering unique engineered features that bring about medical and pharmaceutical advantages, especially in the treatment of diseases. [8] Notably, around 40% of the new molecular entities (NMEs) selected for full-scale development based on their safety and effectiveness ultimately fall short in clinical development due to subpar biopharmaceutical properties.

❖ **Types of Nanotechnology for Drug Delivery:**

These represent the categories of drug delivery systems currently utilized in the field of nanomedicine.

1. Nanobubbles:

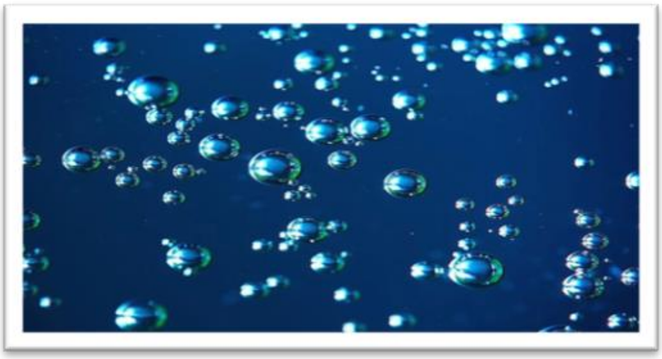


Fig. Nanobubbles.

Nanobubbles, which come into existence at the nanoscale, merge into more stable microbubbles once they reach body temperature. The formation of gas nuclei on hydrophobic surfaces in supersaturated solutions leads to the entrapment of gas, resulting in various types of nanobubbles, including plasmonic nanobubbles, bulk nanobubbles, oscillating nanobubbles, and interfacial nanobubbles. Up to this point, nanobubbles have found successful applications in chemotherapeutic treatments.

2. Carbon Nanotubes:

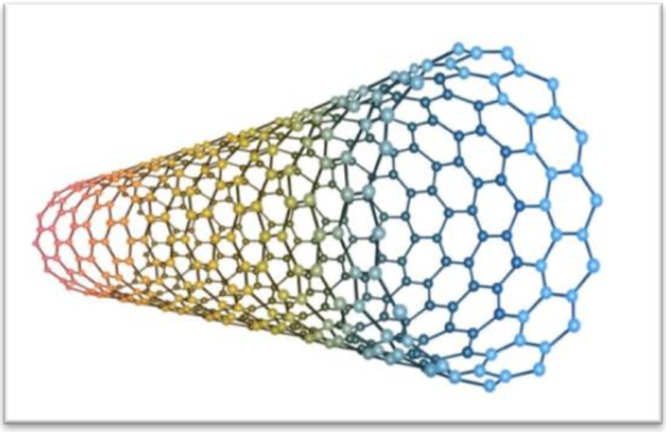


Fig. Carbon Nanotubes

Carbon nanotubes, which are cylindrical carbon-based structures composed of graphite sheets and sealed at one or both ends by buckyballs, come in two widely used designs: single-walled nanotubes and multi-walled nanotubes. These nanotubes, as implied by their name, are frequently employed for encapsulating drugs.

3. Paramagnetic Nanoparticles:

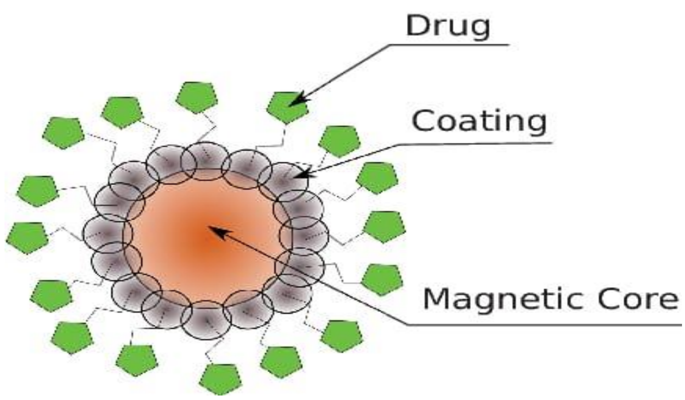


Fig. Paramagnetic Nanoparticles

Paramagnetic nanoparticles serve a dual purpose in both diagnostics and treatment. These nanoparticles can be precisely manipulated using magnetic fields, making them a valuable technology for targeting specific tissues and organs.

4. Quantum Dots:

Fig. Quantum Dots.

Quantum dots are nanocrystal structures with a semiconductor inorganic core and an organic shell, often coated with zinc sulfide to enable them to emit light under specific conditions. Within the field of medicine, quantum dots find applications in transporting various substances, including chemotherapeutic agents, biological materials, and non-biological agents.

5. Liposomes:

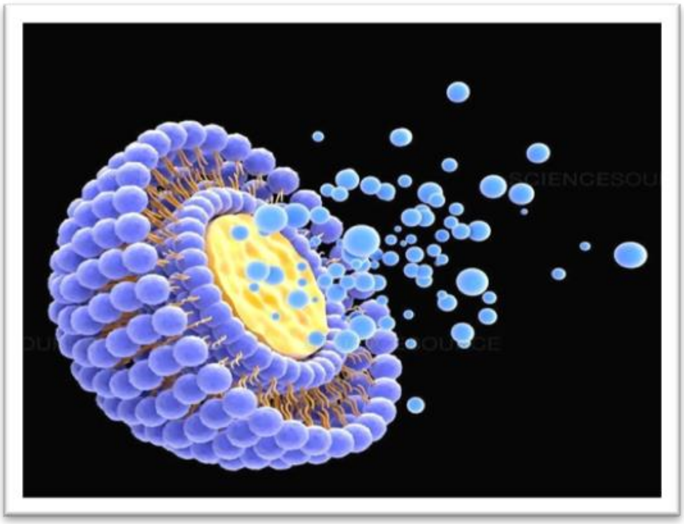


Fig. Liposomes

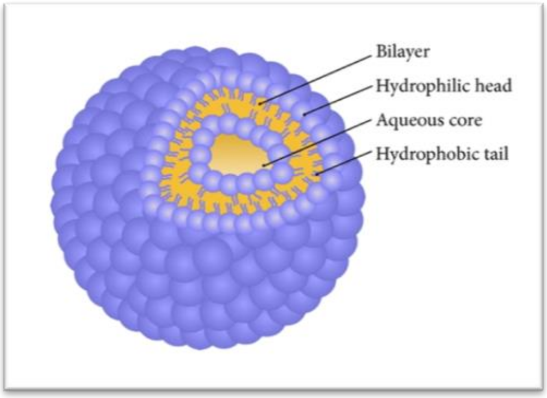
Liposomes are constructed from self-assembling synthetic particles composed of amphiphilic phospholipids. These particles feature an aqueous core domain encircled by double-layered vesicles in a spherical shape. Liposomes stand out as a frequently employed nano drug delivery system due to their favorable attributes of biocompatibility and biodegradability. They are routinely included in clinical trials for applications related to proteins, cancer treatments, and siRNA transfer.

6. Solid lipid nanoparticles:

Solid lipid nanoparticles provide an alternative to liposomes, presenting a controlled colloidal drug delivery system. These nanoparticles are composed of solid lipids and are stabilized by surfactants. [27] They are known for their tolerability, biodegradability, and excellent bioavailability when administered to the eyes. Furthermore, solid lipid nanoparticles show potential for targeting the brain.

Fig. Solid Liquid nanoparticles

7. Niosomes:



Niosomes stand out due to their capability to transport both lipophilic and lipophobic agents. They exhibit excellent stability and can serve as a viable alternative to liposomes, functioning similarly in the body. Niosomes offer promising applications, such as encapsulating potent drugs, antiviral medications, and anticancer treatments. [28]

8. Polymeric Nanoparticles:

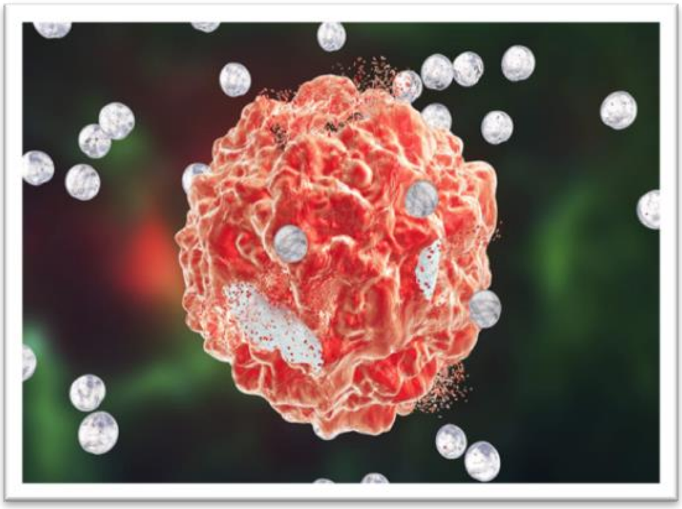


Fig. Polymeric Nanoparticles

Polymeric nanoparticles are commonly favored for nano-drug delivery systems due to their biodegradability and biocompatibility. These nanoparticles come in two main types: vesicular systems, which are also referred to as Nanocapsules, and matrix systems. [26]

9. Nanocapsules:

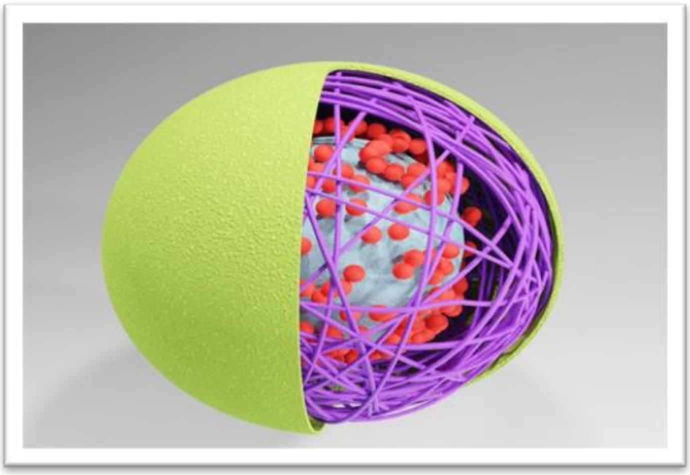


Fig. Nanocapsules.

Nanocapsules are specialized structures designed to transport and distribute Active Pharmaceutical Ingredients (APIs) within the polymeric matrix. Once within the matrix, a nanocapsule can be entrapped, dissolved, or encapsulated. Their versatile engineering allows for tailored medication delivery, making them a promising choice, especially in the context of cancer therapy.

10. Nanoemulsion:

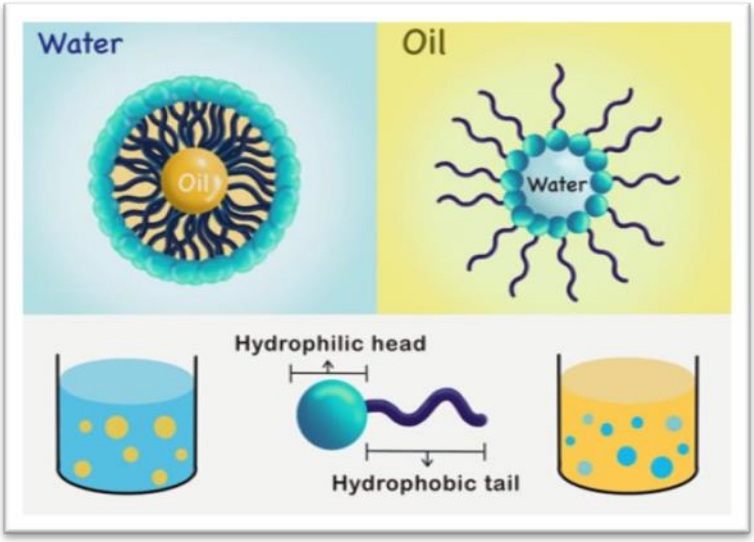


Fig. Nanoemulsion.

Nanoemulsions enhance the bioavailability of drugs with low water solubility. These are non-uniform drug delivery systems consisting of two immiscible liquids, where one liquid contains droplets of the other. [29] Nanoemulsions boost oral bioavailability and facilitate even drug dispersion upon reaching the gastrointestinal tract.

11. Nanoshells:

Nanoshells consist of a silica core enclosed by a metal outer layer, and they can be tailored in various sizes and shapes to target specific conditions and body regions. An advantage of nanoshells is their cost-effectiveness, as they demand only a small quantity of precious metals in the outer layer.

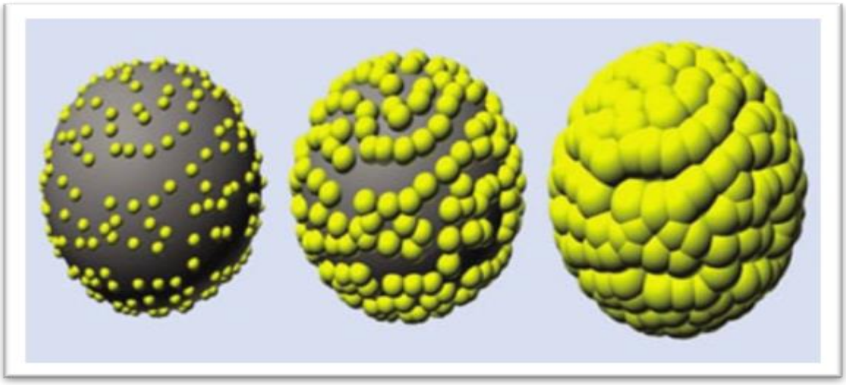


Fig. Nanoshells

12. Dendrimers:

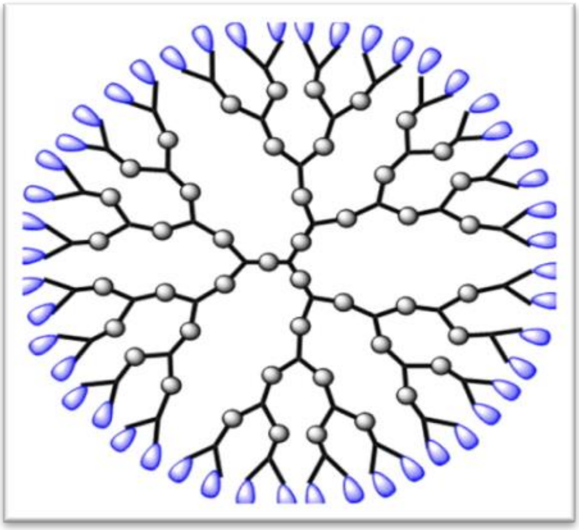


Fig. Dendrimers

Dendrimers, characterized by their controllable size and shape with multiple branches, offer valuable capabilities in entrapping drugs and delivering bioactive substances, encompassing medications, genes, and vaccines.

13. Polymeric micelles:

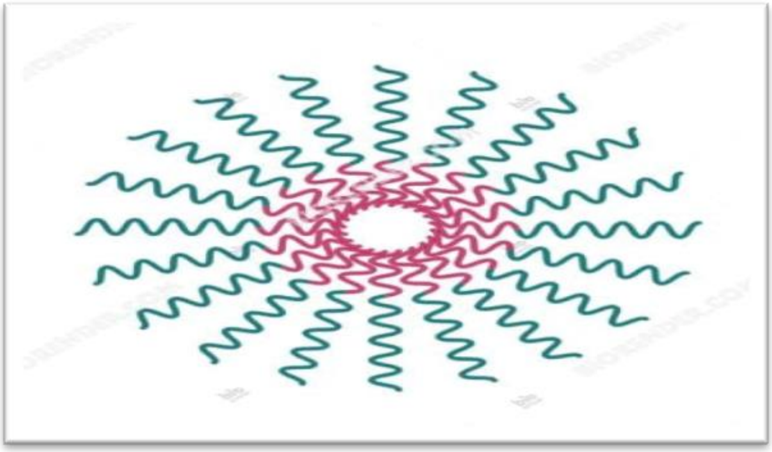


Fig. Polymeric micelles

Polymeric micelles are composed of block copolymers containing both lipophilic and lipophobic monomer units. These micelles, when employed for drug delivery, enhance the solubility of drugs with low water solubility, improve permeability, and mitigate medication side effects. When administered intravenously, polymeric micelles exhibit prolonged circulation in the bloodstream due to protective shielding, reducing their degradation. [9] [10] [11]

❖ **Applications of Nanotechnology Products in Medicine:**

Pharmaceutical nanotechnology, a prominent aspect of nanomedicine, extends beyond drug development and includes advancements in disease detection and prevention through imaging and sensing. It offers the potential for treating diseases through novel medical devices, tissue engineering, and even cellular repair technology. This research is swiftly transitioning into marketable products, sparking heightened interest in further research and investment in the field. [12]

- **Nanoparticles for Bioimaging:**

Several molecular imaging techniques, including optical imaging (OI), magnetic resonance imaging (MRI), ultrasound imaging (USI), positron emission tomography (PET), and more, have been documented for the visualization of biological samples in both in vitro and in vivo settings. [13]

- **In Vitro Diagnostics:**

Emerging sensor designs, utilizing nanotubes, nanowires, cantilevers, or atomic force microscopy, are integrated into diagnostic devices and sensors. These sensors are developed with the goal of enhancing sensitivity, lowering production expenses, or detecting new analytes, such as Alzheimer's plaques, which were previously undetectable until recent advances. [14]

- **Multifunctional Nanoparticles for Cancer Therapy:**

Chitosan nanoparticles, which are biodegradable, were prepared by D. K. Chatterjee and Y. Zhang. They encapsulated quantum dots and underwent appropriate surface modifications to immobilize both a tumor-targeting agent and a chemokine on their surfaces. These engineered nanoparticles facilitated the visualization of interactions between immune cells and tumor cells using an optical microscope. [15] [16]

The utilization of quantum dots in cancer treatment represents a significant advancement. These dots emit a glowing light when exposed to UV light. Upon injection, they penetrate the cancer tumor, enabling surgeons to identify and target the glowing tumor. Moreover, nanotechnology holds promising potential for nerve regeneration in cases of injury. [17]

❖ **Nanotechnology in the Pharmacy Industry:**

Nanotechnology has shown its capability to enhance the delivery of drugs with poor water solubility, enabling better penetration through epithelial and endothelial barriers. It also extends the bioactivity of active pharmaceutical ingredients (APIs) by shielding them from harsh biological conditions. [18] Additionally, pharmaceutical nanotechnologies can be applied to integrate therapeutic and diagnostic functions. Pharmaceutical companies leverage nanotechnology to deliver a wide range of substances, including both organic and inorganic compounds, encompassing materials such as metals, polymers, and carbon nanotubes.

❖ **Nanoparticle as a Drug Delivery System:**

Drug delivery systems (DDS) offer the potential to enhance various essential attributes of "free" drugs, including solubility, in vivo stability, pharmacokinetics, and biodistribution, ultimately improving their effectiveness. Nanoparticles, with their advantageous qualities, can serve as a promising option for drug delivery systems in this regard. [19]

❖ Surgery:

Rice University employs a unique technique using a flesh welder to seamlessly merge two pieces of chicken meat into a single unit. The process involves placing two chicken sections in close proximity and applying a greenish liquid containing nanoshells coated with gold along the seam. An infrared laser is then used to trace the seam, effectively welding the two pieces together. [20] [21] This innovative approach holds the potential to address challenges and minimize blood leaks encountered during surgical procedures like reconnecting arteries in kidney or heart transplants. The flesh welder offers a precise and effective means of welding arteries.

❖ Advantages of Nanotechnology in Drug Delivery System:

- Nanoparticles play a crucial role in parenteral drug formulations. When conventional drugs are administered intravenously, there is a risk of causing embolism. However, nanoparticles, due to their significantly smaller size compared to even the tiniest capillaries in the body, help reduce this risk. [22]

- The size of nanoparticles is not the sole reason for their promise in disease treatment. Many nanoparticles are also biodegradable, making use of biodegradable polymers as carriers. This allows them to be designed to break down under specific physiological conditions, essentially triggering them to release their contents in a particular location in the body. [23] [24]

- Furthermore, nanomedicine can be engineered to resist breakdown by endogenous enzymes. This capability enables controlled release, where a single targeted dose is slowly released over time. This controlled and sustained release not only reduces the frequency of drug administration but also enhances patient compliance and maintains a constant level of the active pharmaceutical ingredient in the body.[25]

❖ CONCLUSION:

Pharmaceutical nanotechnology has become firmly established and is opening doors to enhance materials, medical devices, and the development of new technologies, especially in cases where traditional approaches are nearing their limits. This field brings fresh optimism to the pharmaceutical industry by offering innovative, patentable technologies to offset the revenue loss from off-patent drugs. Across the globe, scientific organizations, industries, and governments are eagerly embracing this technology, recognizing its potential to significantly advance disease detection, diagnosis, therapy, and prevention.

The inception of nanoparticle technology was primarily driven by the need to address challenges related to the solubility and permeability of drugs in development. Nanoparticles provide an enticing platform for a wide range of biological applications. These systems can be tailored in terms of their surface and core properties to serve individual and multimodal purposes, such as biomolecular recognition, therapeutic delivery, biosensing, and bioimaging. Nanoparticles have already found applications in both laboratory and real-world settings. To fully unlock their potential, however, we must address several outstanding issues, including assessing the short-term and long-term health impacts of nanomaterials, developing scalable and reproducible manufacturing methods, and establishing reliable metrics for characterizing these materials.

❖ REFERENCES:

1. .Buzea, C., Pacheco, I.I. and Robbie, K., 2007. "Nanomaterials and nanoparticles: sources and toxicity". Biointerphases, 2(4), pp.MR17-MR71.
2. Allen, T.M., 1994. Long-circulating (sterically stabilized) "liposomes for targeted drug delivery". Trends in pharmacological sciences, 15(7), pp.215-220.
3. Allen, T.M., Hansen, C.B. and Guo, L.S.S., 1993. "Subcutaneous administration of liposomes". a comparison with the intravenous and intraperitoneal routes of injection. Biochimica et Biophysica Acta (BBA)-Biomembranes, 1150(1), pp.9-16.
4. Bailey, R.E., Smith, A.M. and Nie, S., 2004. "Quantum dots in biology and medicine" Physica E: Low-dimensional Systems and Nanostructures, 25(1), pp.1-12.
5. Barichello, J.M., Morishita, M., Takayama, K. and Nagai, T., 1999. "Absorption of insulin from Pluronic" F-127 gels following subcutaneous administration in rats. International Journal of Pharmaceutics, 184(2), pp.189-198.
6. Bibby, D.C., Talmadge, J.E., Dalal, M.K., Kurz, S.G., Chytil, K.M., Barry, S.E., Shand, D.G. and Steiert, M., 2005. "Pharmacokinetics and biodistribution of RGD-targeted doxorubicin-loaded" nanoparticles in tumor-bearing mice. International Journal of Pharmaceutics, 293(1-2), pp.281-290.
7. Carrstensen, H., Mueller, R.H. and Müller, B.W., 1992. "Particle size, surface hydrophobicity and interaction with serum of parenteral fat emulsions and model drug carriers as parameters related to RES uptake". Clinical nutrition, 11(5), pp.289-297.
8. Ferrari, M., 2005. "Cancer nanotechnology": opportunities and challenges. Nature Reviews Cancer, 5(3), pp.161-171.
9. Gwinup, G., Elias, A.N. and Domurat, E.S., 1991. Insulin and C-peptide levels following oral administration of insulin in intestinal-enzyme protected capsules. "General pharmacology", 22(2), pp.243-246.
10. Hargrove, J.T., Maxson, W.S. and Wentz, A.C., 1989. "Absorption of oral progesterone is influenced by vehicle and particle size". American Journal of obstetrics and gynecology, 161(4), pp.948-951.
11. Hawley, A.E., Davis, S.S. and Illum, L., 1995. Targeting of colloids to lymph nodes: influence of lymphatic physiology and colloidal characteristics. Advanced Drug Delivery Reviews, 17(1), pp.129-148.

12. Heiati, H., Tawashi, R. and Phillips, N.C., 1998. “Solid lipid nanoparticles as drug carriers” II. Plasma stability and biodistribution of solid lipid nanoparticles containing the lipophilic prodrug 3′-azido-3′-deoxythymidine palmitate in mice. International Journal of Pharmaceutics, 174(1-2), pp.71-80.
13. Ja, D., 2002. “The price of innovation: new estimates of drug development costs”. Journal of Health Economics.
14. Jain, S. and Jain, N.K., 2002. “Liposomes as drug carriers”. Controlled and novel drug delivery. 2nd ed. CBS publisher, New Delhi, pp.304-52.
15. Kirby, C., Clarke, J. and Gregoriadis, G., 1980. “Effect of the cholesterol content of small unilamellar liposomes on their stability in vivo and in vitro”. Biochemical Journal, 186(2), pp.591-598.
16. Lasic, D.D., Martin, F.J., Gabizon, A., Huang, S.K. and Papahadjopoulos, D., 1991. “Sterically stabilized liposomes”: a hypothesis on the molecular origin of the extended circulation times. Biochimica et Biophysica Acta (BBA)-Biomembranes, 1070(1), pp.187-192.
17. Li, A.P., Kaminski, D.L. and Rasmussen, A., 1995. “Substrates of human hepatic cytochrome P450 3A4”. Toxicology, 104(1-3), pp.1-8.
18. Lipinski, C.A., 2000. “Drug-like properties and the causes of poor solubility and poor permeability”. Journal of pharmacological and toxicological methods, 44(1), pp.235-249.
19. Lipinski, C.A., Lombardo, F., Dominy, B.W. and Feeney, P.J., 2012. “Experimental and computational approaches to estimate solubility and permeability in drug discovery and development settings”. Advanced drug delivery reviews, 64, pp.4-17.
20. Moghimi, S.M. and Szebeni, J., 2003. Stealth liposomes and long circulating nanoparticles: “critical issues in pharmacokinetics, opsonization and protein-binding properties”. Progress in lipid research, 42(6), pp.463-478.
21. Nimmerfall, F. and Rosenthaler, J., 1980. “Dependence of area under the curve on proquazone particle size and in vitro dissolution rate”. Journal of Pharmaceutical Sciences, 69(5), pp.605-607.
22. Olivier, J.C., 2005. “Drug transport to the brain with targeted nanoparticles”. NeuroRx, 2(1), pp.108-119.
23. Owens III, D.E. and Peppas, N.A., 2006. “Opsonization, biodistribution, and pharmacokinetics of polymeric nanoparticles”. International journal of pharmaceutics, 307(1), pp.93-102.
24. Pan, Y., Li, Y.J., Zhao, H.Y., Zheng, J.M., Xu, H., Wei, G. and Hao, J.S., 2002. “Bioadhesive polysaccharide in protein delivery system”: chitosan nanoparticles improve the intestinal absorption of insulin in vivo. International Journal of Pharmaceutics, 249(1-2), pp.139-147.
25. Saini, R., Saini, S. and Sharma, S., 2010. “Nanotechnology: the future medicine”. Journal of cutaneous and aesthetic surgery, 3(1), p.32.
26. Sakuma, S., Suzuki, N., Kikuchi, H., Hiwatari, K.I., Arikawa, K., Kishida, A. and Akashi, M., 1997. “Absorption enhancement of orally administered salmon calcitonin by polystyrene nanoparticles having poly (N-isopropylacrylamide) branches on their surfaces”. International Journal of Pharmaceutics, 158(1), pp.69-78.
27. TM, A., 1989. “Liposomes with prolonged circulation times: Factors affecting uptake by reticuloendothelial and other tissues”. Biochim Biophys Acta, 981, pp.27-35.
28. Torchilin, V.P. and Trubetskoy, V.S., 1995. “Which polymers can make nanoparticulate drug carriers long-circulating”. Advanced drug delivery reviews, 16(2-3), pp.141-155.
29. Tümer, A., Kirby, C., Senior, J. and Gregoriadis, G., 1983. “Fate of cholesterol-rich liposomes after subcutaneous injection into rats”. Biochimica et Biophysica Acta (BBA)-General Subjects, 760(1), pp.119-125.
30. Xu, J.P., Ji, J., Chen, W.D. and Shen, J.C., 2005. “Novel biomimetic polymersomes as polymer therapeutics for drug delivery”. Journal of controlled release, 107(3), pp.502-512.