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# Bio-inspired Nanotechnologies as Drug Delivery System

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## Abstract

**Technological developments in healthcare have been at the center of focus during last decade. The rise of Nano therapeutic platforms has seen recent advancements in combating deadly diseases like cancer. A lot of research is already done on nanotechnology systems like liposomes, Nano emulsions, dendrimers and micelles, and recently carbon nanotubes and quantum dots have been in focus for their therapeutic and diagnostic capabilities. Most of these systems are utilized to improve the solubility and bioavailability profiles of certain drugs along with targeting capabilities to some extent. However, toxicological and environmental concerns of the nanomaterial used in these systems have raised alarm among researchers and thus forcing investigators for finding new gateways to delivery of drugs to target sites. During this decade there's been a sharp rise in bio-inspired and biomimetic drug delivery systems. Bio-inspired platforms mimic the natural components inside the body making them more safe and effective in delivering drugs.**

***Keywords: Nanomedicine; Bio-inspired; Biomimetic; Drug Delivery***

## Introduction

Since its introduction decades ago nanotechnology has delivered promising solutions in healthcare industry. Nanotechnology has been widely used for both diagnostic and therapeutic purposes. Platforms like liposomes [1], dendrimers [2], Nano emulsions [3], micelles [4], and carbon nanotubes [5] have been effectively utilized for treatment of cancer. These systems also offer advantage of minimizing the drawbacks associated with the drugs like solubility, stability and bioavailability. Nanotechnology has touched all realms of life including food and cosmetic industry [6]. The success is widely embraced in the scientific community offering newer applications day by day. However, some researchers have raised a genuine concern related to toxicity of nanomaterial inside body [7]. Since nanoparticles are extremely small in size they reach deep inside tissues and cells. Investigators have concern regarding its elimination from the body. Some investigations reveal that inorganic nanomaterial get deposited deep into the tissues and cause serious side effects to human body. Use of organic and

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biodegradable substances in Nano formulation has minimized this problem to some extent. However a complete safe and reliable approach is a necessity for successful delivery of drugs. This is where bio-inspired delivery systems show its importance. It has been observed that imitating nature's way of transporting substances and cells inside the body could help in enhancing the pharmacological activity and reducing the unavoidable side effects associated with drugs [8].

**Development of bio-inspired delivery systems**

Advanced drug delivery system behaves like a supercomputer. It offers both 'hardware' and 'software' components that controls the handling and administration of drug and regulates the local or systemic release and also sense the microenvironment through which the drug has to pass in the route towards the action site. Bio-inspired drug delivery systems are designed familiar to biological molecules which are continuously transported inside the body. Biomimetic has been recently defined as an emerging field of science that includes the study of how Nature designs, processes and assembles/disassembles molecular building blocks to fabricate high performance soft materials and mineral-polymer composites, and then applies these designs and processes to engineer new molecules and materials with unique properties [9]. Biological molecules like erythrocytes, bacterial ghosts and genetically engineered stem and dendritic cells have been widely used and accepted for drug delivery purposes [10]. Their unique properties make them suitable for *in-vivo* investigations. For example, resealed erythrocytes have been widely exploited for delivery of nanoparticles. Drugs could be incorporated inside the core of RBCs or attached onto the surface for successful delivery of medicaments [10-12]. Bacteria use fimbriae and flagella filaments to attach themselves to human mucosa. This unique property of bacteria could be exploited in muco adhesive drug delivery of nanoparticles [13]. Similar inspirations have been drawn from Velcro-like hook-and-loop fasteners, Gecko-inspired (geometric-based) adhesives and mussel adhesive proteins for successful drug delivery [14].

Drugs delivered via bio-inspired mechanisms tend to remain inside the human body for longer duration and develop unique strategies to evade the host immune systems [15-16]. Bacteria that are used for development of bio-inspired delivery systems are non-pathogenic and generally regarded as safe (GRAS). Some of them include *Lactococcus lactis* which is utilized for protein production and *Streptococcus gordonii* have ability to colonize mucosal surface in oral, nasal and vaginal cavity [17-18]. Apart from producing cytokines and enzymes [19] attenuated pathogenic bacteria have also been used to target tumors [20]. Similarly investigators developed a Nano machine termed as 'microbots' which are basically bacteria which have been used to load nanoparticles for successful delivery at desired sites [21].

Another biologically inspired molecule is the Virus-like particle (VLP). These virus derived particles are self-assembled particles of capsid or envelope proteins, homogenous in size and morphology and are non-infectious due to absence of genetic material [22]. Viruses like particles have been incorporated into liposomes (referred to as virosomes) for vaccine delivery. siRNA, nucleic acids, peptides and/ or proteins, and antitumor drugs could also be loaded in virosomes for delivery to target sites. Industrially virosomes can be easily manufactured at a relatively low cost [23].

Various body cells like RBCs, stem cells, macrophages and dentritic cells have been actively studied for various biomedical applications. Red blood cells (RBCs) have capability to circulate and deliver oxygen for a prolonged period of time, owing to

their unique shape, mechanical properties and the presence of a self-marker on their surface. RBCs can be used either for the continuous release of drugs into the circulatory system or for targeted drug delivery to specific organs. Owing to their prolonged circulation time (~120 days) and slow rate of drug release they have been widely investigated for targeted delivery of drugs [23].

Macrophages are essential component of immune system. These can also be exploited for delivery of drugs. These have advantage to phagocytose nanoparticles and are re-injected into the body as 'Trojan horse' for therapeutic delivery [24].

Another bio-inspired delivery system is engineering of lymphocytes as therapeutic drug carriers. Drugs could be conjugated onto the surface of B and T cells. In a study B cells and T cells were grafted with polyelectrolyte multilayer patches -disc-shaped thin polymer films that are ~300 nm in thickness and several micrometers in diameter that had a cell-adhesive face to enable cell attachment, termed a 'cellular backpack' [25].

Stem cells have been widely used for delivery of genetic material *in-vivo*. Now they are also utilized for delivery of nanoparticles. Roger et al. have demonstrated that non-transformed, non-immortalized adult human mesenchymal stem cells are able to internalize polymeric and lipid nanoparticles without affecting the viability, differentiation or ability of MSCs to migrate to brain tumors [26].

## Conclusion

The development of bio-inspired drug delivery system is a rapidly emerging field. Bacteria, viruses, lymphocytes, macrophages and stem cells have been widely investigated for drug delivery. Nature inspired structures that mimic *in-vivo* organelles could be developed for successful delivery of drugs inside human body.

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