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# Nanoscale device for veterinay technology: Trends and future prospective

**Neeraj Dilbaghi, Harmanmeet Kaur, Ritesh Kumar, Pooja Arora, Sandeep Kumar***

*Department of Bio and Nano Technology, Guru Jambheshwar University of Science and Technology, Hisar, Haryana 125001, India*

*Corresponding author. Tel: (+91)1662-263500; Fax: (+91) 1662-263500; E-mail: ksandeep36@yahoo.com

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## ABSTRACT

Nanotechnology is an interdisciplinary science comprising of various disciplines such as physics, chemistry, electronics, material science, health science, biology and veterinary science. The ability to manufacture and manipulate material at nanoscale has offered opportunities to interface biological systems with outer world in new ways and with unprecedented precision. Veterinary science deals with all non human animals including wildlife and domesticated animals, livestock, working animals and companion animals. Nanotechnology has contributed in revolutionizing health and veterinary sciences by providing new tools and new materials for molecular and cellular biology that are beneficial for living organisms. The variety of nanomaterials that are used for diagnosis and treatment include metallic nanoparticle, quantum dots, carbon nanotubes, magnetic nanoparticles, fullerenes, liposomes, dendrimers and engineered hybrid nanoparticles. However, at present, little data is available on the ecotoxicological and toxicological effects associated with these nanomaterials and hence there is a need to address these issues as physiological properties of nanomaterials are expected to influence their biological response. It is believed that in the upcoming years, nanotechnology will reform the science and technology of the animal health and will help to boost up the livestock production. Nanotechnology based techniques like bioanalytical nanosensors, nanofluidics, targeted drug delivery etc has the potential to solve problems related to diagnosis and treatment of diseases. In this review, we emphasize on how nanotechnology is swiftly changing the diagnosis and treatment patterns at faster and low cost in less time duration. There can be numerous applications of nanotechnology in disease diagnosis, treatment, drug delivery, animal nutrition, animal breeding, tissue engineering and animal identity verification. The role of nanotechnology in veterinary sciences is chiefly discussed as how nanomaterials can modernize the present life. Copyright © 2013 VBRI press.

**Keywords:** Nanotechnology; veterinary; diagnosis; treatment; nanomaterials.

**Neeraj Dilbaghi** got his PhD degree in Microbiology from CCS Haryana Agricultural University, Hisar in the year 1997 and is currently working as Associate Professor and Chairman, Department of Bio and Nano Technology, Guru Jambheshwar University of Science and Technology, Hisar, Haryana, India. He has published more than 100 research papers in peer reviewed international journals and conference proceedings. His current research is focused on Biosensors, nanomedicine, drug delivery and toxicological evaluation of nanomaterials.

**Sandeep Kumar** obtained PhD (Nano Science and Technology) from Panjab University, Chandigarh in the year 2008 and is currently working as Assistant Professor, Department of Bio and Nano Technology, Guru Jambheshwar University of Science and Technology, Hisar, Haryana, India. His main research activities are in the area of synthesis and characterization of nanomaterials, electrical characterization of carbon nanotubes, water purification and toxicological evaluation of nanomaterials.

## Introduction

The recent scientific advances in nanomedicine research and global initiatives to support nanotechnology research reflect that nanotechnology based products are revolutionizing the modern medicine in humans as well as animals. Scientists of various fields such as engineering, material science, food, biomedical sciences, environmental science, agriculture, energy and information technology should be abreast with and employ nanotechnology, as appropriate, for the advancement of research and development in order to improve the quality of human life. In this era of new health related technologies, veterinary medicine is entering a new phase of incredible transformations. The major contributor to these changes is our recent ability to measure, manipulate and organize matter at the nanoscale level. Since minute structures are created by nanotechnology, hence they can be used within the body, within the cells for diagnosing and treatment of diseases. Nanotechnology has the potential to have great impact on diagnosis and treatment of humans and animals.

 

Unique size dependent properties of nanoparticles have numerous diagnostic applications such as diagnostic biosensors, imaging nanoprobes for magnetic resonance imaging contrast agents **[1]**. Key global challenges associated with animal production include environmental sustainability, human health, disease control, and food security. Nanotechnology holds a major promise for animal health, veterinary medicine, and other areas of animal production **[2-5]**. Welfare of animals, animal safety derived products; risks to the environment, human health, and industry consolidation are amongst the main concerns that are likely to extend from biotechnology to nanotechnology **[6]**. Nanotechnology has made major advancements in imaging by allowing medical practitioners to view inside the body, inspect and image soft tissues and provide better diagnosis judgment. Using nanotechnology multifunctional nanomaterials can be designed to image a specific organ, target tissue, access deep molecular targets and provide drug at controlled release. Great advances have been and are being made in nanobiochip materials, nanoscale biomimetic materials, nanomotors, nanocomposite materials, interface biomaterials and nanobiosensor with enormous prospect in industrial and clinical medicine applications **[7]**. Nanotechnology has also a key role in treatment of diseases by the development of smart drug delivery systems which provides time controlled spatially targeted, self regulated, pre-programmed and effective dosage of drugs to the site of disease. One particular application of nanotechnology in medicine currently being developed involves employing nanoparticles to deliver drugs, heat, light or other substances to specific types of cells (such as cancer cells). Particles are engineered so that they are attracted to diseased cells that allow direct treatment of those cells. The development of such technique reduces damage to healthy cells in the body and allows for earlier detection of disease. Researchers across the world are also developing nanoparticles to defeat viruses. The nanoparticle does not actually destroy virus molecules but delivers an enzyme that prevents the reproduction of virus molecules in the patient's bloodstream. There are efforts underway to develop oral administration of several different drugs using a variety of nanoparticles. Nanorobots are other promising area in healthcare that could actually be programmed to repair specific diseased cells, functioning in a similar way to antibodies in our natural healing processes. There are varieties of nanomaterials that are probed nowadays for their probable use in diverse applications e.g buckyballs (trapping free radicals generated during allergic reactions), nanoshells (to destroy cancer cells using IR radiations), aluminosilicate nanoparticles (to reduce bleeding), carbon nanotubes (sensors and drug delivery), gold nanoparticles (diagnosis, labeling agents), nanocrystalline silver (antimicrobial agent), nanorobots (individual cell repair), iron oxide nanoparticles (improved MRI imaging). This review article focuses on wide range of nanomaterials used for diagnosing and treatment of animal diseases.

## Disease diagnosis

Nanotechnology has the potential to provide cheaper, fast and precise diagnostic tools in the hospitals. Diseases can be treated with minimum ease and can be eliminated from our body if they are detected earlier. These days, nanomaterials are playing a key role in imaging and monitoring and hence earlier detection of disease. The advancement in imaging and monitoring of diseases has a huge effect on animal health care. Better diagnosis has a positive effect in the cost of animal health care. In past, conventional methods like imaging were only possible to certain tissues and bones which take hours to days to provide us results. In contrast, with advancement in technology, nanotechnology allows medical professional and practitioners to diagnose in the body and provide results in few minutes. Bionanomaterial based research has emerged as a new exciting field and DNA, RNA and peptides are considered as important bionanomaterials for the fundamental development in life sciences **[8]**. The nanomaterials such as quantum dots, nanoshells, carbon nanotubes can be synthesized and functionalized which may couple with the imaging sources and accompany the molecule with ultrasound, magnetic resonance, X-rays techniques to diagnose the targeted organ effectively. Quantum dots are of great interest in diagnosis due to their size dependent optical properties like fluorescence, high extinction coefficients, broad absorption spectra and narrow emission spectra [**9**]. Multifunctional magnetic nanoparticles also have major applications in diagnosis and therapy of biological organisms **[10-11]**. Numerous glimpses of diagnosis such as nanoarrays and nanochips, used as test platforms for diagnosis of molecular interactions are reported in literature **[12-13]**. With the advancement in technology, new nanotools are emerging that produce smart contrast agents and improve optical imaging and can contribute in the earlier stages of disease diagnosis. Likewise targeted ultrasonic contrast agents are used for molecular imaging and therapy. Molecular imaging is pursued in all non invasive medical imaging such as nuclear, magnetic resonance imaging, ultrasound and optical techniques **[14-15]**. Diagnosis at molecular level as well as single cell can be detected by nanosensors and nanochips. These help to diagnose monitor and treat diseases. Various nanomaterials are discussed below that are used as nanosensors and nanochips for diagnosis. Of all the discussed nanomaterials, quantum dots and gold nanoparticles show finest results in diagnosis.

### *Nanochips*

Over the past two decades, there has been a considerable effort to develop methods for rapid detection of diseases. Earlier detection of disease causing pathogens was done by wide range of assays like enzyme immunosorbent assay, western blot assay, polymerase chain reaction, neutralization, agar-gel immunodiffusion. The above named assays suffer from varied drawbacks that can be overcomed by nanochips providing rapid and specific diagnosis. Nanochips, miniatured devices carry out integrated diagnosis by refined and minimally invasive procedures. Nanochips have diverse range of applications ranging from recognizing genes, guiding drug delivery to monitoring body functions and perceive life science and chemical pathogens. Nanochips are also applied for identification of certain diseases like cystic fibrosis and scanning of DNA for signs of predispositions of other ailments **[16-19]**. Nanochips have been employed to detect gene mutations responsible for monogenic disorders that help to determine etiology of complex diseases including heart disease, diabetes and neuro psychiatric traits. Recently, in 2010 US researchers developed silver sputtered nanochip that mimic the connectivity between neurons in the brain **[20]**. John et al. in 2011 has developed a new bionanochip sensor for the detection of premalignant and malignant cells in oral cancer. Programmable nanochip was developed by McDevitt in Rice University for the detection of heart disease and cancer with small saliva sample **[21]**. Thus, nanochip technology has tremendous potential as a diagnostic tool which will also be effective for targeted drug delivery in future.

*Nanosensors*

Principles of nanotechnology have been exploited in biosensing that detects analytes of very small amounts at very low concentrations **[22-26]**. Nanosensors are miniature devices that can diagnose samples which use biological material or tissue based on biorecognition element which is immobilized on the surface of physicochemical transducer. Nanosensors are envisioned from the integration of chemical, physical and biological devices which work together as a sensor at nanoscale. Majorly, nanosensors are based on two detection principles - catalytic and affinity sensing. Catalytic sensors utilize enzymes, cells, tissues/organelles and microorganisms as the recognition agent. Affinity sensors are those which utilize whole antibodies, antibody fragments, nucleic acid/aptamers, receptors, lectins, phages, novel engineered scaffold derived bonding proteins, molecular imprinted polymers, plastic antibodies and synthetic protein binding agents as the recognition agent **[27-40]**. Nanosensors have wide range of applications in medical area. Nanosensors have major role in veterinary sciences, they use very small amount of a chemical contaminant, virus or bacteria which is helpful for agriculture and food systems that in return improves the feedstock **[2]**.

For online detection of veterinary drug residues in milk, porcine bile and bovine urine, a commercially handled robot was designed with the help of Surface Plasmon Resonance (SPR) technique. This technique has a key impact on the development of new optical biosensors **[41]**. In 2000 scientist have established sulfamethazine in animal urine by optical immunosensor **[42]**. Laterly in 2000 whole cell biosensor was developed by three gene systems *V. fischeri*, *E. coli* and *Aquorea Victoria* with inducible promoter tetracycline **[43]**. Recently, an artificial nose was constructed to diagnose cancer at an early stage in very less time by laboratory of nanomaterial-based devices. This artificial nose is an electronic system which is based on nanotechnology, simulating the dog's sense of smell and smelling cancer in its early stage **[44]**. Later in 2010, scientist investigated the use of electronic noses to detect tuberculosis from sputum samples **[45]**. In 2011, fiberoptic sensors were designed for *in vivo* monitoring of individual living cells. These fiberoptic sensors are designed by immobilization of bioreceptors on the fiber tip for detecting the target molecules **[46]**. Various nanomaterials are used for the fabrication of sensors which are able to detect abnormal physiological health of an animal due to disease incidence. Nanowires have been used for making extremely small, sensitive and electronic based nanosensors for the detection of biological species **[16]**. In 2002, scientists reported carbon nanotube (CNT) based sensors that were implanted under skin for providing real time measurement of blood estradiol changes in animals. These implanted sensors have a major role in veterinary sciences as: once swallowed or implanted, these are capable of continuously sending data throughout the life of the animal and later to track animal products after slaughtering **[47]**. Applications of nanosensors open great prospectives ranging from whole body monitoring to diagnosing various diseases due to their unprecedented sensitivity. Various nanomaterials employed for diagnosis and treatment of diseases are illustrated in **Fig. 1**.

*Nanomaterials*

Liopsomes: Liposomes are small artificial vesicles of spherical shape composed of single or multiple concentric bilayers, size ranging from 50-500 nm. Liposomes are formed in aqueous medium by self assembly of amphiphilic molecules such as phospholipids in which the polar head groups are located at the surface of the membranes when in contact with the aqueous medium, whereas the fatty acid chains form the hydrophobic core of the membranes, shielded from the water. Liposomes play a key role in diagnosis as they can be used as carriers for radioisotopes and contrast agents. They can also be used to detect hepatic metastases and blood perfusion imaging. In 1988 the rat hepatic metastases has shown that paramagnetic liposomes had high normal liver concentration, while liver metastasis had low accumulation. Liposome can be used in blood pool or perfusion imaging based on contrast enhancement **[48]**. The potential of paramagnetic liposomes in blood pool and perfusion imaging was proven by various *ex vivo* and *in vivo* animal studies **[49]**. Liposomes may also be applied in lymphatic imaging by subcutaneous administration **[50]**. Magnetic resonance (MR) molecular imaging with target paramagnetic/ superparamagnetic liposomes may be more challenging compared to molecular imaging using radio labelled liposomes and gamma photon imaging, due to its lower sensitivity. Recent studies have shown that MR molecular imaging with liposome systems is practical via targeting to certain biomolecules **[51-52]**.

Dendrimers: Dendrimers discovered in 1880 are macromolecules which are highly branched. The objective for synthesizing dendrimers, is to improve the pharmacokinetic behavior of currently available small-sized compounds from a broad extracellular to an intravascular distribution **[53]**. These are potential polymeric carriers, which are currently under investigation as contrast agents for magnetic resonance imaging (MRI), scintigraphy, X-ray techniques and computed tomography (CT). Major target studies of dendrimers include angiography, tissue perfusion determination, tumor detection and differentiation. Most relevant example of dendrimers in diagnosis is metal chelates that are used as imaging moieties for MRI and scintigraphy and triiodobenzene derivatives for computed tomography. However, more research is needed before a dendrimeric contrast agent can finally become available for widespread use in patients.

  

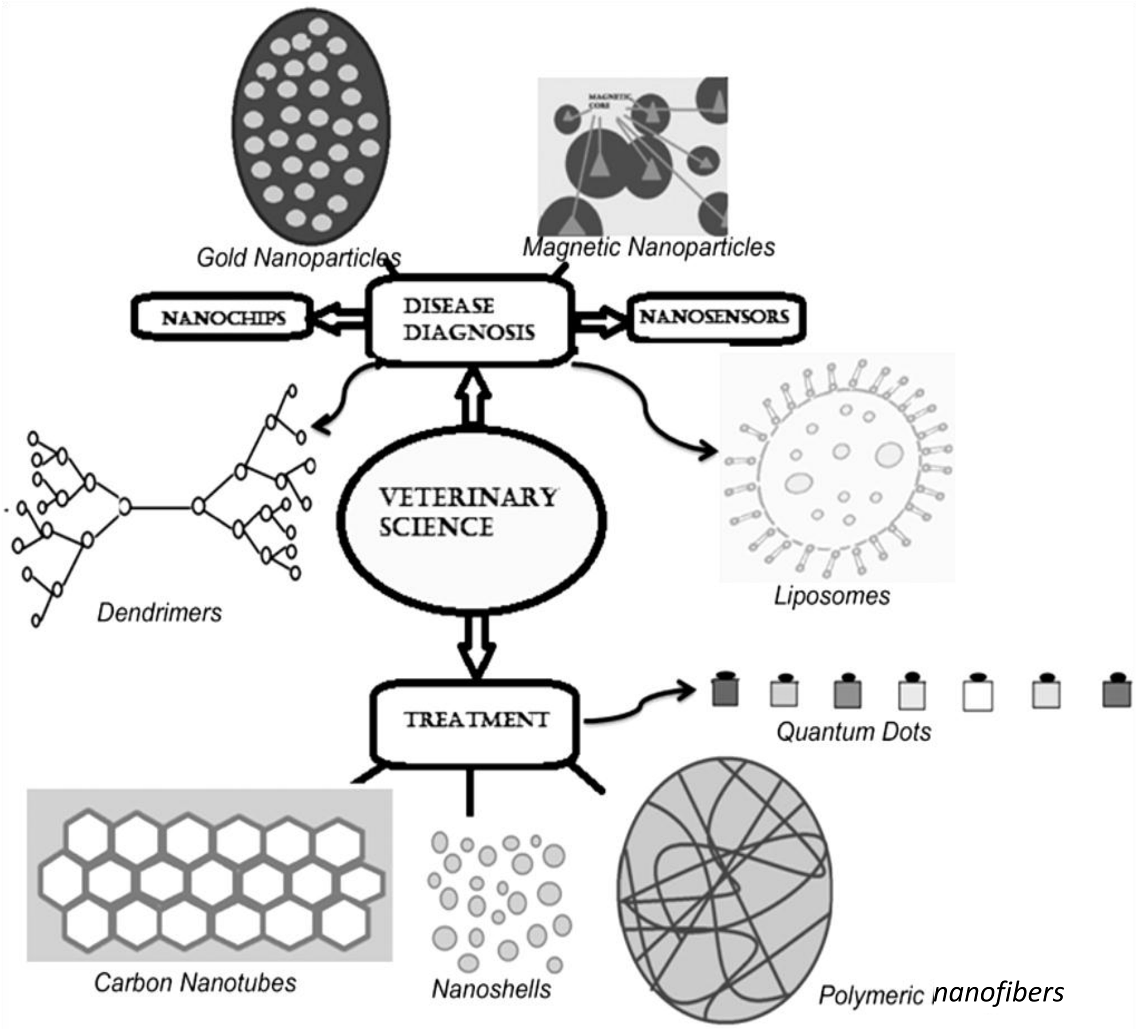


**Fig. 1.** Various nanomaterials employed for diagnosis and treatment.

**Table 1.** Various nanoparticles used in diagnosing and treatment of wide variety of animals.

| **Nanoparticles** | **Applications** | **Animals** | **Ref.** |
|---|---|---|---|
| Gold Nanoshells | Whole blood immunoassay | Mice | Hirsch et al., 2003 |
| Polymeric nanoparticles | In vivo fluorescence imaging | Mice | Ghoroghchian et al., 2009 |
| Iron-oxide nanoparticles | Enhanced MRI of atherosclerotic plaques | Rabbit | Schmitz et al., 2000 |
| Quantum dots | Imaging of antigen specific T-cell receptor response | Macaques (Monkeys) | Chen et al., 2008 |
| Quantum dots encapsulated in micelles | In vivo imaging | Frog | Dubertret et al., 2002 |
| Ferri-magnetic Iron-oxide nanoparticles | In vivo MRI of<br>Transplanted Syngeneic islets<br>Islet engraftment | <br>Rats<br>Swine | Nohyun et al., 2011 |
| Inorganic luminescent nanoparticles | In vivo optical imaging | Mouse | Chermont et al., 2007 |
| Selenium nanoparticles | Against hepatic injury | Mice | Wang et al., 2005 |
| Liposomes | Anti-tumor activity against mammary tumor glands | Rats | Abbasalipourkabir et al., 2010 |
| Peptide conjugated gold nanoparticles | in vitro cytotoxic effects on mouse ovarian surface epithelial cell lines (MOSEC) | Mouse | Tran et al., 2011 |

Quantum dots: Quantum dots are semiconductor nanocrystals having unique properties like high level of photostablility, tunable optical properties, single-wavelength excitation and size-tunable emission. The above discussed properties make quantum dots as one of the most capable therapeutic nanomaterial and highly acquiescent to biological and clinical applications. Due to their extremely small size (around 10 nm in diameter), they are used as fluorescent probes for biomolecular and cellular imaging **[54-58]**. Quantum dots (QDs) enables high sensitive detection of analytes at low concentrations due to their similar quantum efficiencies **[59]**. Diseases involving large number of genes and proteins can be detected by multicolour quantum dot probe that helps in imaging and tracking multiple molecular targets simultaneously **[60]**. These applications lead quantum dots to be ideally used for biosensing. Quantum dots hold great potential as photodynamic therapy agent where these can be multimodelled to monitor as well as treat disease tissues **[61]**. The positive results obtained so far have shown accomplishment of QDs in biological systems and different biomedical applications.

Gold nanoparticles: Gold nanoparticles have proven to be the most flexible nanostructures, due to their ability to control size, shape, composition, structure, assembly, encapsulation thereby resulting in enhanced optical properties. They exhibit a unique phenomenon termed as surface plasmon resonance which is responsible for their large absorption and scattering cross-sections. Thus, gold nanoparticles are attractively used in biomedical applications **[62]**. Gold nanoparticles can be functionalized easily with biological molecules such as antibiotics and nucleic acid using various strategies and can be employed for diagnosis. Gold nanoparticles upon aggregation change its colour as an example when gold nanoparticles are functionalized with ssDNA, which is capable of specifically hybridizing to a complementary target for the detection of specific nucleic acid sequences in biological samples, their properties change **[63]**. Gold nanoparticles are also used as a core that can be modified with a wide variety of surface functionalities to provide selective nanoprobes for diagnosis **[64]**. Au nanoparticles can be coupled with metal deposition which helps in providing enhanced sensing **[65]**. The attractive features of gold nanoparticles such as ease of synthesis, non-cytotoxicity, high biocompatibility, broad optical properties make them fascinating for diagnosis.

Magnetic nanoparticles: Magnetic nanoparticles are finding increasing applications in the areas of medical diagnostic and therapeutic because of the advantageous properties associated with them such as lesser dipole dipole interactions, lower sedimentation rates, facilitation in tissue diffusion, high magnetization so as to be controlled by external magnetic fields and to reach the targeted pathologic tissue and their small size that make them available for circulation through the capillary systems of organs and tissues. Magnetic nanoparticles are based on the specific characteristics of magnetic nanomaterials and the beneficent relationships between the magnetic fields and biological systems. Magnetic nanoparticles are found to have attractive magnetic and hydrodynamic properties **[66]**. They are often used for the development of biological sensors, immunoassays, cell separation, protein binding studies and biochips. Magnetic nanoparticles (MNPs) have various applications like contrasts for magnetic resonance image, magnetic hyperthermia, magnetic separation, drug delivery, fluorescence-modified superparamagnetism, intracellular uptake and use in cellular imaging. Magnetic nanoparticles show effective results in animal body as they can easily move in liquid medium and thus can be excited magnetically or detected inside nonmagnetic tissue **[67-69]**. Magnetic nanoparticles have been widely used in the early diagnosis of diseases. They are especially important for some fatal diseases such as cancer. Some magnetic nanoparticles like iron oxide nanoparticles have been used in perfusion imaging for *in-vivo* characterization of tumors **[70]**. Wide variety of nanoparticles used in diagnosis and treatment of animals are illustrated in **Table 1**.

## Treatment

Veterinary health care is highly visible and growing concern for the pet owners and the government. Keeping in view the higher costs of medications and veterinary care, and increasing pet population the need for innovative solutions is urgent. The effective delivery of therapeutic molecules has been a major barrier to obtain targeted response against the disease agent. Many drugs are effective in treating diseases but most of them also have certain limitations with regard to toxicity, poor aqueous solubility and cell impermeability. The drawbacks discussed above can be solved by nanomedicine. Nanomedicine has the potential to solve unique biological challenges. New drugs and new delivery systems both come under "nanomedicine" umbrella. Therapeutic and diagnostic agents are at the forefront projects of nanomedicine and research is focused on rational delivery and targeting of pharmaceuticals in animals **[71]**. Nanopharmaceuticals, the most promising and productive area of nanotechnology application in animal treatment involves nanoparticles as these have relatively higher intracellular uptake compared to microparticles and hence they are available for broad range of biological targets owing to their small size and higher mobility. Nanopharmaceuticals engross encapsulating the material to generate nanoparticle which thereby improves solubility, diffusion and degradation characteristics of the encapsulated material and, nanomaterials that can carry drugs to the targeted site **[72]**. Various nanomaterials are used in the treatment of veterinary diseases like polymeric nanoparticles, carbon nanotubes, liposomes, dendrimers, nanoshells, nanopores, magnetic nanoparticles, etc. The main challenge is to design the various novel devices and technologies with the help of above discussed nanomaterials which will enable to guide the therapeutics to its correct location of action and will certify that pharmacological activity is maintained for an adequate duration.

### *Polymeric nanoparticles*

Strategies for controlled drug-delivery have made a considerable progress in the field of medicine where polymeric nanoparticles play a key role. Polymeric nanoparticles are the most promising drug carriers due to their structural and functional characteristics. They deliver drugs for long periods, increasing the drug efficacy, maximizing the patient compliance thereby enhancing the ability to use highly toxic, poorly soluble or relatively unstable drugs. They are used for the development of highly selective and efficient therapeutic and diagnostic modalities **[73-75]**. Polymeric nanoparticles can circulate freely in the body and penetrate tissues by means of mechanisms such as endocytosis. The uptake of nanoparticles depends on the various factors such as particle size, surface charge and surface hydrophobicity. Steric stabilization of nanoparticles has been achieved by making the surface of nanoparticles more hydrophilic so as to prevent opsonization in the blood stream. This is done either by adsorbing hydrophilic surfactants on nanoparticle surface or using block/branched copolymers **[76]**. Natural polysaccharides like, chitosan and its derivatives, alginate, dextran, pullulan, hyaluronic acid and chondroitin sulfate have prominent effect as they are biodegradable in nature. Varieties of synthetic polymers are also used for synthesis of nanoparticles such as poly-lactic acid (PLA), poly-glycolic acid (PGA), poly-lactic-co-glycolic acid (PLGA) and polyanhydride. Polymeric nanoparticles form a versatile drug delivery system as they can potentially overcome physiological barriers, and guide the drugs to specific cells or intracellular compartments **[77-78]**.

*Carbon nanotubes*

Carbon nanotubes (CNTs) have fascinated scientists with its extraordinary properties. These nanomaterials have become increasingly popular in various fields because of their extremely small size and amazing optical, electronic and magnetic properties when used alone or with modifications. CNTs are graphene sheets rolled up into the cylinderical shape which may be open or closed at the ends. To be precise, they are graphene cylinders which have diameter in nanoscale and capped with end-containing pentagonal rings. Carbon nanotubes have potential therapeutic applications in the field of drug delivery **[79]**. Carbon nanotubes have emerged as a new alternative tool, efficient in transporting and translocating the therapeutic molecules. They can be functionalized by various biomolecules such as bioactive peptides, proteins, nucleic acids and drugs, and are used to deliver their cargos to cells and organs **[80]**. Carbon nanotubes can also be used for encapsulation of molecules thereby providing material storage application as well as protection and controlled release of loaded molecules **[81]**. Carbon nanotubes show effectiveness in treatment of wide range of diseases but its major role is in cancer treatment. CNTs on combination with anticancer drugs, enhances their chemotherapeutic effects. Galanzha et al. had reported the paclitaxel loaded PEG-CNTs for cancer therapeutics **[82]**. Gannon et al. in 2007 reported a non-invasive and selective thermal destruction of cancerous cells with the help of functionalized single walled-CNTs which were heated on exposure to radiofrequency field **[83]**. This enabled the use of CNTs as an interesting tool in the field of therapeutic oncology. Single walled-CNTs coated with PEG chains linked to RGD peptide, have been reported for effective targeting of integrin positive tumor in mice **[84]**. When single walled-CNTs were injected into mice, activation of blood platelets has been reported due to formation of light/dye-induced thrombus **[85]**. CNTs also work at their best in tissue regeneration by conjugating with biodegradable polymers and these can be used for the development of scaffold nanomaterials in tissue regeneration **[86-87]**. Thus, carbon nanotubes have a potential to revolutionize health care sector for wide future applications.

*Dendrimers*

Diversity of molecules holds potential therapeutic value out of which dendrimers clutch a wide applicability in drug delivery. Dendrimers have many flexible branches containing voids where drug molecules can be physically trapped **[88]**. This dense architecture enables an excellent encapsulation. Their structure made a significant impact in the area of nanotechnology for providing well controlled functional building blocks. They have a range of applications from drug delivery to drug diagnosis. Dendrimers are effectively used in drug delivery as they deliver a drug at controlled rate by chemically modifying them either by fine tuning of hydrolytic release conditions and the selective leakage of drug molecules on the basis of their size or shape or by pH-sensitive materials **[89-90]**. Dendrimers with high payload also showed rapid pharmacological response with improved efficacy **[91]**. Dendrimers have their major stress in the treatment of cancer as these nanometric particles passively accumulate at the site of tumors **[92]**. As reported earlier dendrimers also have the potential of significantly enhancing the solubility of NSAIDs (Non-steroidal Anti inflammatory Drugs). The recent research indicates that dendrimers might be considered as potential drug carriers for treatment of diseases with the capability to provide a sustained release along with reduced side effects.

*Nanoshells*

Nanoshells are concentric particles in which one material is coated with a thin layer of another material by various synthesis methods. They are multifunctional with tailored properties. Nanoshells are dielectric metal nanospheres. Nanoshells have unique optical properties that totally depend upon the size of that particle, thus its surface plasmon resonance can be tuned in broad spectrum of wavelength. Foremost methods of synthesizing nanoshells are layer by layer precipitation and one pot synthesis. Till date varieties of nanoshells are synthesized out of which gold nanoshells gave fruitful results to destroy the cancer completely **[93]**. Nanoshells are currently being used in cancer chemotherapy and still more applications are conceived in the treatment of diseases. They can also be used to immobilize cells or viruses, to trap and embed small and macromolecules on surfaces **[94]**. Thus nanoshells can provide numerous advances in medicine and can revolutionize methods used in medical science.

*Quantum dots*

As described earlier in diagnosis section, quantum dots are semiconductor nanocrystals which fluoresce on excitation with a light source. Recent developments have shown that quantum dots with near-infrared emission can be applied for biopsy and surgery of cancer patients. Conjugation of quantum dots with various biomolecules such as peptides, antibodies, etc. can be used *in vivo* for targeting tumours **[95]**. Recently, researchers from North Carolina state university have developed extremely small microneedles that are used to deliver quantum dots into the skin that opened the door for treatment of skin cancer **[96]**. Quantum dots are revolutionizing the field of targeted drug delivery and are considered as one of the major components of multifunctional nanodevices that can provide treatment to animals.

*Liposomes*

Liposomes have been extensively used as a potential drug delivery system due to their diversity of structure. Structurally liposomes are made up of amphiphillic unilamellar/ multilamellar membranes of natural lipids. Liposomes can encapsulate hydrophobic drugs within the membrane and hydrophilic drugs in their aqueous spaces. Liposomes interact with cells and release the drug contents in one of the four ways: adsorption, lipid exchange, fusion or endocytosis. Thus liposomes are considered as one of the best drug delivery systems. They are also used as adjuvants for vaccination, solubilizers for various ingredients and immunological enhancers. Earlier studies reported the use of amphoterecin B encapsulated liposome used for the treatment of fungal infections which also reduce the renal toxicity and used for the treatment of drug resistant leishmaniaisis **[97]**. Researchers had already studied the liposome based delivery for the treatment of cancer, inflammations. Thus liposomes establish themselves as an important model drug delivery system.

*Nanogels and ceramic nanoparticles*

Hydrogels when miniaturized forms nanogels which are generally formulated using solvent evaporation or emulsification technique. Nanogel particles can be used for loading oligonucleotides which are stable in aqueous phase, do not agglomerate, get inserted within intestinal cell layers. Oligonucleotide coated nanogels do not degrade with time and are effective in gene transcription **[98-99]**. Ceramic nanoparticles with entrapped biomolecules based systems reflect an emerging area for healthcare and have great potential in drug delivery. Nanoparticles consisting of calcium phosphate, silica, alumina or titanium are known as ceramic nanoparticles. They have a wide variety of advantages such as high biocompatibility, low size range, high stability, easier synthesizing techniques **[100-101]**. Their ultra low size range helps them to evade by the reticulo endothelial systems **[102-104]**. Apart from these, polymersomes, which are hollow shell nanoparticles, are also employed for the delivery of the drug to the targeted site. These are synthesized using amphiphilic block copolymers **[105-106]**. They have the advantage to break down in acidic medium and release the drug within cell endosomes **[107-108]**.

*Toxicity assessment*

The advancements in diagnosis and treatment using nanoscience depend in part on exploiting the size specific properties of nanoscale materials. These size dependent properties also lead to the possibility of size dependent biological activity. The exotic feature of nanomaterials enables nanoscale particles to cross or circumvent barriers that are impenetrable to larger particles. Many biological processes occur at nanoscale and hence there are numerous opportunities for precisely sized nanoparticles to interfere with normal biological functions. These unique behaviours of nanoparticles (i.e to interact with biological systems) are requiring new tools and concepts within this field of toxicology to understand and predict how emerging engineered nanoparticles will interact with humans and animals. Kumar et al have recently investigated the cellular response of metal oxide nanoparticles on vero cell lines and highlighted many reasons that can be associated with toxic behaviour of these nanoparticles **[109]**. Advancement in technology and research offer possibility of generating new types of nanostructured materials with designed surface and structural properties **[110-111]** but there is a lack of information concerning their impact on human health and environment **[112]**. In light of the above, it is mandatory that each new nanomaterial must be subjected to new health and safety assessment prior to its commercial and public use.

## Conclusion

In the recent years, the application of nanotechnology in human and veterinary medicine has shown a great progress. Researchers believe that progress in the field of nanotechnology could represent a major breakthrough in addressing various technical challenges faced by medical and veterinary professionals. Nanotechnology and its applications are specific and varied in continuous development, with a high potential for improving domestic animals production, and flora and fauna in general. The present review highlighted how nanotechnology has influenced the healthcare of animals both in diagnosis and in treatment. Nanomaterials such as carbon nanotubes, quantum dots, liposomes, polymeric nanoparticles, magnetic nanoparticles, etc. are explored for their potential use in diagnosis and treatment of diseases. The above discussed nanomaterials are used for early diagnosis, which includes detection of molecular interactions with use of nanoarrays, and nanochips. Nanomaterials offer a vast number of breakthroughs like cost effective and faster approach that will further advance the clinical aspect of veterinary sciences in future. In the future, it can be conceived that bacterial infections can be eliminated in the patient within minutes, instead of using treatment with antibiotics over a period of weeks. With the advancement in technology, we can expect to generate capability to perform surgery at cellular level, thereby removing individual diseased cells and even repairing defective portions of the individual cells. Innovations in technology and identification of novel hybrid materials with time will provide significant lengthening of the human lifespan by repairing cellular level conditions that cause the body to age. Several nanotechnology based products are already in the market and many are under development or in experimental stages. Nanomaterials have revolutionized the field of diagnosis and treatment but at the same time these particles have the potential to affect vital organs of the body. Thus, extensive research is still required to support the effectiveness, and mainly the safety of nanotechnology, avoiding any harm to the environment or to human beings and animals.

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