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# A REVIEW ON NANOTECHNOLOGICAL ASPECTS IN VETERINARY MEDICINE

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**ABSTRACT:** Nanoscience and technology is a fascinating and fast developing sector of science and technology that deals with atomic, molecular, and macromolecular scales. Nanotechnology is concerned with nanoscale manipulation and the use of diverse tools and functional materials. In 1959, American Nobel Laureate Richard Feynman suggested the notion of nanotechnology for the first time. However, in the 1980s, the underlying concept of definition and popularization was examined in greater depth. Nanotechnology has opened up new vistas for applications in molecular biology and biotechnology, which has revolutionized practically every area of veterinary and animal science by introducing new, small-scale instruments and materials that are advantageous to live animals. Nanomaterials of various sorts are utilized in illness detection, therapy, medication delivery, animal feeding, and animal breeding. Metallic nanoparticles, quantum dots, carbon nanotubes, magnetic nanoparticles, fullerenes, liposomes, and Dendrimers are among the nanoparticles employed. For considerable advantages, scientists, engineers, and biologists should work at the cellular and molecular levels, and the public should be informed of the possible hazards.



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## 1. INTRODUCTION

### 1.1 Nanoscience at a Glance

Nanotechnology is a multidisciplinary subject that studies and manipulates physical matter at the nanoscale, combining of natural, mathematical, computer, and material sciences. Engineers have known since 1950 that manufactured submicron structures, which are the same size as biological molecules, offer unrivalled potential. The rapid progress of applied nanotechnology, on the other hand, did not begin until 1990. This is owing to the development and availability of electron microscopies such as scanning tunneling microscopy (STM) and the atomic force microscope (AFM). These methods allow for the exact observation and manipulation of nanoscale physical matter, leading to an increasing interest in nanoscience studies. Nanotechnology was considered the sixth really breakthrough technology produced in the modern era by the year 2000, and it was universally recognized as a milestone invention. Since the beginning of time, there has been a saying that "necessity is the mother of invention." As an outcome, researchers are motivated to support research and develop it into useful technology. Since the beginning of civilization, humans have used materials to fulfil their basic needs. Materials have always been important in the evolution of human civilization. Material science is one of the subjects that is always evolving, and its progress is a sign of civilization [1]. Humans most likely used gold as the first elemental metal [2]. After gold, copper became the second metal used by mankind. This is supported by archaeological investigations of the Indus Valley civilizations. Scientists and researchers are increasingly focusing on customizing materials to obtain desired qualities at the atomic level [3]. Although nanoparticles are commonly regarded as a recent scientific discovery, they have a long history. As early as the 9th century, artists in Mesopotamia used nanoparticles to create a dazzling effect on the surface of pots. Pottery from the Middle Ages and Modern Ages frequently featured a gold or copper coloured metallic glitter that may still be seen today.

Two aspects motivate the research of nanostructured materials:

i. They have unique properties at nanoscale that are not seen in bulk materials and
ii. The utilization of these features in technologies (especially those connected to health, known as bio-mimic nanotechnology) for the benefit of humanity.

The desire to produce nature's mimic and manipulate materials at identical length scales attracted attention in nanostructured materials research. The interesting characteristics and attractive forms of biomaterials have prompted researchers to develop novel nanomaterials with precise control over their size and shape [4]. These nanostructured materials have unique size and shape-dependent properties and might be utilized in a variety of scientific and industrial applications. As a result, recent technological advances have made it easier to develop structures or fabricate devices smaller than 100 nm in size but with considerable functional advantages over older electronics, pushing us closer to the revolution's threshold. It has the ability to completely revolutionize the existing technical area. The promises appear to be so enormous that they may even meet the millennium goal of providing cost - effective services to all man-kind. Nanotechnology is rapidly being utilised in a wide range of applications, including agriculture, electronics, automobiles, and textiles, as well as bio-medicinal applications [5,6]. Nanotechnology research has evolved in significance in recent years as a leading-edge multidisciplinary technology involving physical science, chemical science, biological sciences, and materials science [7]. A material having a size of $10^{-9}$ m, or 1000 times smaller than a μm, is referred to as Nano. Nanoscience and nanotechnology all deal with Nanoscience, Nano engineering, and nanotechnology all deal with items and systems that are extremely small in size. Nanostructures are considered to exist on the boundary between the tiniest man-made item and the largest molecule in a biological system. Due to our ability to control and manipulate nanostructure, we will be able to develop novel chemical, physical, and biological characteristics of systems that are intermediate in size between individual atoms and bulk materials. Nanotechnology and allied scientific fields now constitute the entire range of activity leading to the expected next industrialization.The dimension of nanomaterials can be used to classify them. Consider the three-dimensional space vectors of a certain nanomaterial. At that time, nanomaterial that is within the critical size range of 1-100 nm in all three dimensions is defined as a 0-D particle or quantum dot, for example Si, Ge, ZnS quantum dots, etc. Similarly, if nanomaterial growth in a 2-dimension vector is restricted to a critical range of 1-100 nm, allowing nanomaterial to grow only in the 3rd direction, the obtained nanomaterial is defined as a 1-D nanomaterial, example quantum wires, Nano-rods, Nano-wires, single walled carbon nanotubes, and so on. Only one dimension of a

2-D nanomaterial is confined to that critical range, allowing nanomaterials to develop in 2-Dimension vectors, such as Graphene sheets [8]. Figure 1.1 illustrates this approach.

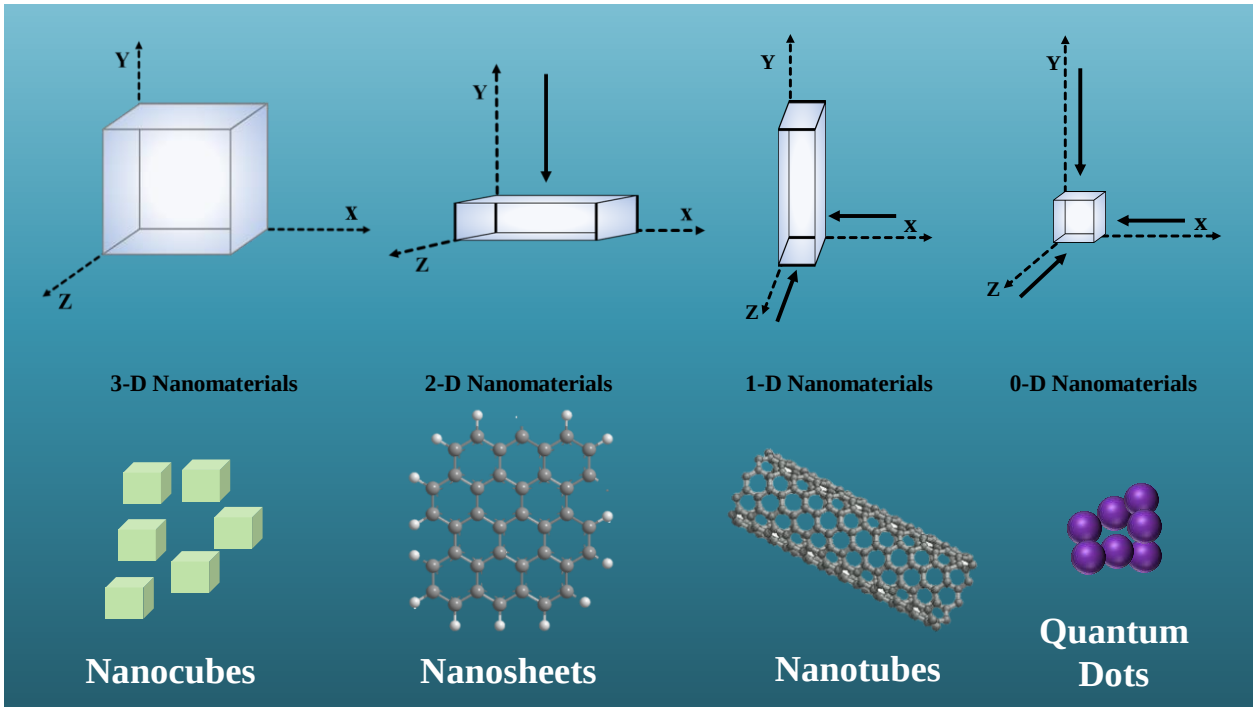


**Fig. 1.1:** 0-D, 1-D, 2-D and 3-D nanomaterials

Similarly, core-shell particles are a kind of nanomaterial that has a different chemical composition on the outside than it does in the inside [9]. Non-metallic nanomaterials, which are composed of non-metals and organic molecules, exhibit unique electrical behaviour that may be modified to be insulating or conducting depending on their size and composition. Fullerenes are the most well-known non-metallic nanoparticles, and they have applications in superconductors and medicine [10]. Carbon nanotubes are another well-known class of nanomaterials that can be metallic or semiconducting depending on their diameter and chirality.

### 1.1.2 Development in the field of Nanotechnology

Though the phrase "nanotechnology" has recently gained popularity and recognition, it has existed for many years before the name was coined. Ayurveda is an ancient medical therapy that has its roots in the Rigveda, a 5000-year-old Indian medical tradition. Nanotechnology is something it is familiar with. Metals were utilized in the *Samhita* era in the form of *Ayaskrati* powder. The usage of *Ayaskrati* was restricted since its fineness did not allow it to be free of hazardous consequences. *Rasashashtra's* creation has changed the Ayurvedic medical system. Metals and minerals are turned into a very fine absorbable, therapeutically most effective, and least or non-toxic type of medication called as *Bhasma* using a variety of novel pharmaceutical procedures such as *Shodhan, Jaran,* and *Maran* [11,12]. *Bhasma* is a powdered version of a substance formed by calcinations. Nanoparticles

have been around for a long time, according to history. In 1570, alchemists described using nanoparticles as aurum potable (potable gold) and Luna potable (potable silver), which they employed as elixirs [13]. However, one of the first applications of nanoparticles that we find in literature is the employment of gold nanoparticles for colouring glassware, such as the Lycurgus cup from the 4th century AD [14]. However, the genesis of nano-structured materials' remarkable optical qualities may be traced back to the 17th century, when the bright colour of some of these nanoparticles was employed to build cathedral stained glass windows. Due to the existence of metallic gold nanoparticles, particularly in colloidal form, Faraday explained the origin of their colour [15]. Mie used Maxwell's equation [16] to theoretically explain the formation of colour in these nanoparticles. Nanomaterials research, on the other hand, is still in its early stages. This is owing to the progress of electron microscopes, which can reveal the structure of nanomaterials. Nanotechnology fever is rapidly sweeping nearly all areas of science and technology, and the general public is experiencing the true meaning of Nobel Laureate Richard Smalley's quote: "Just wait – the next century is going to be incredible. We are about to build things that works on smallest possible length scales, atom by atom. These little nano-things will revolutionize our industries and our lives" [17]. This is becoming increasingly clear in the form of nanoparticle potential applications, which include anti-bacterial [18], textile [19], catalysis [20], and medical sciences [21]. A notable feature of nanomaterials is that a variety of parameters, including size, shape, surface composition, dielectric environment, and inter-particle interactions, may impact their characteristics [22].

**Significance of *Bhasma***

*Bhasma*, when taken in tiny doses and with no discernible flavour, has a rapid onset of action. How is it possible for *Bhasma* to have all of the aforementioned characteristics? It is dependent on *Bhasmikaran* methods. Minerals and metals are not effective as medicine in their coarse form, but as their shape transforms from macro to microscopic, they demonstrate therapeutic characteristics. When we look at the many steps of *Bhasma* preparation, we can see that at each level, an effort is made to generate finer particles. Between the *Shodhan* and *Bhavana* processes, one intermediary step called Jaran is done for metals with low melting points (Pb, Sn, & Zn). Metals are melted and combined with some plant medicine powder before being rubbed with an iron ladle on the inside surface of the pot until the metal is completely iron.

***Kapipakwa* technique**

*Bhasma* are made in this approach by putting metals (Cu, Zn, Au) to a four-stage operation (*shodhana, Kajjali, Bhavana* and *kupipakwa*). After amalgamating Shodhan metals with mercury, purified Sulphur is combined and triturated till a black, lustreless, fine and smooth mass is formed.

This is known as *Kajjali* preparation. For a specific amount of time, prepared *Kajjali* is levigated by specific liquid medium. It is allowed to dry completely before being put into glass bottles (*Kach kuppi*) that have been coated with seven layers of mud-smeared fabric. After that, the bottle is placed in a sand bath (*Valukayantra*) for indirect and homogenous heating for a set amount of time. After breaking the self-cooling container, sublime product is collected from the neck and *Bhasma* is collected from the bottom and processed to powder form.

**Changes during Bhasma preparation**

During *Shodhana*, heat is used to enhance tension in matter, resulting expansion. In liquid media, after heating, there is a drop in tension by immediate cooling and an increase in compression force. The disruption of compressive tension equilibrium caused by repeated heating and cooling results in increased brittleness, reduced hardness, and finally reduced particle size. Some metals and minerals react with oxygen in air and produce chemical compounds when they are red hot. When iron is red hot, it combines with oxygen in the air to create ferroso ferric oxide ($Fe_3O_4$). Copper is transformed to copper sulphate in humid air, which entirely decomposes into cupric oxide when exposed to extreme heat. Materials with liquid are rubbed between the surfaces of the pestle and mortar in the *Bhavana* process. This method includes rubbing materials between two surfaces to break them down. Particle surfaces chip and produce minute particles when stress is applied in the form of attrition. Wet grinding eliminates dust problems. Wet grinding produces finer particles than dry grinding. Metals oxidise during the Jaran process when they are heated in the open air. Metals' melting points rise as a result of oxidation. Metals receive trace materials from the inorganic part of plant material. Compounds are produced on the metal surface during incineration. The particle size decreases as the operation is repeated. Metals usually transform to their compound forms after maran, which are biologically beneficial to the body.

**Characterization of Bhasma:**

Physical Properties:

***Colour (Varna)***: Each Bhasma is assigned a distinct colour. A change in colour shows that Bhasma is not adequately created. This is because during Bhasma creation, a specific compound is generated, and each compound has its own distinct colour.

***Nishchandratvam***: Before using Bhasma for therapeutic purposes, it must be *Nishchandra*, or lustreless. Metals have a lustre known as *chandratatva*. Metal lustre should not remain after appropriate burning. This can be determined by putting a sunlight on the metal. If there is still lustre, it needs to be incinerated again.

***Varitara***: This test is used to detect how light and fine Bhasma is. The floating character of Bhasma in stagnant water can be used to determine this. The surface tension law is used in this test. Bhasma is taken between the index finger and thumb and sprinkled over the surface of stagnant water. Bhasma that has been properly incinerated will float on the surface.

***Unama Test***: This test is a variation of the *Varitara* test. On the surface of the floating Bhasma, a small grain of rice is placed. It is regarded excellent if the Bhasma is still floating while carrying the weight of rice.

***Rekhapurnata***: This test is used to determine how fine *Bhama* is. The size of the bhasma should be such that it is easy to absorb and assimilate into the body. Bhasma should be so fine that it fills the furrows between your fingers. To see if the particle can fill furrows, a small amount of Bhasma is rubbed between the index finger and thumb.

***Slakshnavtam***: Bhasma creates this tactile sense by simply touching the figure tips. Slakshna Bhasma can be taken and assimilated in the body without irritating the mucous membrane of the gastrointestinal system when it is properly incinerated.

***Susukshama***: This denotes the quality of the Bhasma that has been made. *Susukshama* Bhasma is required for easy absorption in the body.

***Anjana Sannibha***: Anjana has a smooth texture and does not irritate the skin when used. Bhasma that has been properly incinerated should be smooth and not irritate mucus membranes.

***Particle size***: Bhasma should be provided in *Churna* form. Bhasma particles should be the similar size as pollen grains from the Pandanus *odorantidissimus* flower.

***Gatarsatvam***: Bhasma that has been properly incinerated should have a distinct flavour. This denotes the change of a metallic flavour into a specific compound flavour.

**Particulars of Nanostructure formation by Mechanical activation**

Bhasmas are closer to nanocrystalline materials. Nanocrystalline materials are solids made up of crystallites having a size of less than 100 nm in at least one dimension. Koch et al. were the first to propose that nanocrystalline materials form during mechanical alloying and milling [23]. The fact that similar crystalline sizes may be achieved using traditional ball mills and other methods suggests that the smallest possible grain size by mechanical milling is determined by total strain rather than milling energy. Various milling parameters have a significant impact on the grain size and product phase that can be achieved. The final consequence of these processes is the *Ayurvedic* concept of *Mardana* and *Bhavana*, which reduces particle size.

### 1.2 Properties of nanoparticles

The characteristics of the material at the nanoscale differ from those of the bulk state [24]. Nanoparticles continue to pique the curiosity of scientists from many fields of study due to their potential for advantageous variations in optical, mechanical, thermal, and electrical characteristics. Up to the micrometre level, the materials maintain their normal physical and chemical characteristics. However, when their size decreases on a micro-level, they begin to display startlingly unique features. However, the qualities of nanoparticles are influenced not only by their size, but also by other parameters such as form, stabilising agent, and production process. Differences in mechanical, optical, magnetic, and electronic properties, are noticeable at the nanoscale. Those properties are discussed briefly further down.

#### 1.2.1 Mechanical properties

The mechanical toughness is determined by a number of factors, including dislocations, impurities, and the surface-to-volume ratio [25]. The mechanical strength of a material diminishes as the number of flaws increases. The grain size determines the material's strength and hardness. 1-D nanomaterials have higher mechanical strength due to their tiny cross section and low number of defects. However, nanoparticles' capacity to withstand severe tensile deformation without breaking their structure has been widely documented and is known as super-plasticity [26] The increased surface-to-volume ratio of nanoparticles creates a new local environment for the surface atoms, which changes magnetic coupling and interactions with nearby atoms, and hence changes mechanical characteristics.

Nanomaterials may be strong than bulk materials. The Hall-Petch effect can be used to determine the connection between material strength and grain size,

$$\sigma_y = \sigma_0 + \frac{k_y}{\sqrt{d}} \qquad (1.1)$$

Where $\sigma_y$ is the yield stress, $\sigma_o$ is the material constant, $k_y$ is the strengthening coefficient and d is the average grain diameter. Theoretically, if the grain size is made infinite low, a material may be made significantly hard.

#### 1.2.2 Optical properties

Optical characteristics have become particularly important in the research of noble metallic nanostructures. This is owing to the fact that they have an absorption profile that is dependent on size, shape, surrounding medium, and composition, as well as the phenomena of surface Plasmon resonance [27]. The optical characteristics of metal nanoparticles differ from those of their bulk counterparts. The optical qualities are proportional to the size of the object. In the form of a colloidal

solution, gold, a yellowish metal, may be created in a variety of colours. The way the nanostructure interacts with light determines the colour of the butterfly. Nanoparticles have an absorption profile that varies from visible to near-infrared depending on their size and shape. Within a particular size range, gold, silver, and copper nanoparticles are known to have distinct optical characteristics in the visible and near-infrared regions.

**Surface plasmon resonance:** It arises as a result of electromagnetic waves interacting with an electron cloud on the surface of metal nanoparticles. The collective oscillation of electrons in a solid or liquid triggered by incoming electromagnetic waves is known as surface plasmon resonance (SPR). When the frequency of photons equals the natural frequency of surface electrons oscillating against the restoring force of positive nuclei, the resonance condition is produced [28]. Localized surface plasmon resonance is another name for SPR in nanomaterials. Many conventional techniques for detecting substance absorption onto flat metal surfaces or the surface of metal nanoparticles are based on SPR.

### 1.2.3 Magnetic properties

The magnetic properties of noble metallic nanoparticles differ from those of bulk in two ways. The high surface to volume ratio, which leads in the development of various local environments for surface atoms in their magnetic coupling/interaction with nearby atoms, is one of the causes for the above-mentioned feature [29]. The second reason for this is that, unlike bulk ferromagnetic materials, which normally have numerous magnetic domains, several tiny ferromagnetic particles may only have one. The supermagnetism occurs in single particles, where the magnetization of the particles is randomly dispersed and they are aligned only when a magnetic field is supplied, and the alignment dissipates when the magnetic field is removed. Optical recording or storage medium, super-magnets, and other commercial and research uses use this phenomenon. Due to its vast use in different sectors such as catalysis, biomedicine, magnetic resonance imaging, magnetic particle imaging, data storage, environmental cleanup, optical filters, and so on, magnetic characteristics have been the subject of considerable study in recent days [30].

### 1.2.4 Electronic Properties

When the particle size enters nano meter level, electronic motion is restricted to a smaller space compared to mean free path of electrons leading to the stronger confinement of electronic motion (spatial confinement). These materials do not follow the classical theory of electronic motion which exhibit quantum effect. The quantization of electronic motion in metallic nanoparticles restricts them into certain discrete energy levels making the valence and conduction band no longer in-separable. The energy gap between valence band and conduction bond (Kubo gap) becomes comparable to or

larger than thermal energy (KBT) at certain size regime and hence metallic nanoparticles become semiconductor and further reduction of size causes higher confinement and reaches a stage when the material becomes an insulator [68]. At this stage materials behave differently towards various perturbations and exhibit properties not achievable from its individual counterparts or from the bulk. Apart from the size dependence of various properties of nanomaterials, they also exhibit interesting shape dependence due to the execution of electronic motion in different dimensions. For example, electronic tunneling phenomenon is observed for 0-D nanostructures which is the key concept used for building artificial atoms and devices like single electron transistors [69]. Similarly, the electron can oscillate in two distinct ways in 1-D nanostructures under electromagnetic field, namely in longitudinal and transverse modes. The way electrons execute its motion alters their various properties and thus nano-rods and nano-tubes give rise to Surface Plasmon absorption peaks due to the two different types of electronic motion.

### 1.3 Synthetic Routes of nanoparticles

Nanoparticle synthesis and assembly processes usually use liquid, solid, or gas phase precursors, apply chemical or physical deposition techniques, and depend on chemical reactivity or physical compaction to integrate the nanostructure building blocks into the final material structure. The following is a list of techniques that may be categorized as top-down or bottom-up approaches:

#### 1.3.1 Laboratory synthesis of nanoparticles

In the case of nanoparticles formation, the solution must be supersaturated for nucleation to occur, either by dissolving the solute at a higher temperature and cooling at a lower temperature or by adding the required reactant during the process to generate the supersaturated solution. The nucleation stage is followed by the particle growth step in the precipitation process. In most circumstances, nucleation and growth occur simultaneously during particle formation, resulting in a broad size distribution in the final product. It is necessary to separate nucleation from growth in order to create monodisperse particles. Nanoparticles are minuscule and, due to their high aspect ratio, are not thermodynamically stable. If the surface is not protected, they will try to join with other particles, resulting in a bulk structure. In comparison to materials made out of macroscopic things, nanomaterials are always thermodynamically unstable. As a result, they may be manufactured at a sufficiently low temperature to regulate their development kinetically rather than thermodynamically.

#### 1.3.2 Top down and bottom up approach for NP synthesis

As demonstrated in figure 1.2, synthesizing nanoparticles can be done from the top down or from the bottom up. Nanoparticles were mostly synthesized via a top-down strategy in the past. The top-

down strategy includes mechanically slicing down bulk metals, with the resultant particles being stabilized by colloidal protective chemicals. Physical and chemical treatments are used to reduce the size of the object. Metal vapor deposition techniques are an example of laboratory synthesis utilizing a top-down approach. However, this technology has a few disadvantages, including the difficulty of obtaining a tight particle size distribution and the high difficulty of installing metal vapour machines. Another disadvantage of physical techniques is the considerable energy consumption required to sustain the high temperature and pressure required for the synthesis step. Most bioprocesses, on the other hand, take place at normal air pressure and temperature, resulting in significant energy savings36. Because the surface chemistry and other physical attributes of nanoparticles are heavily reliant on the surface structure, top-down manufacturing methods produce defects in the product's surface structure, which is a severe restriction.

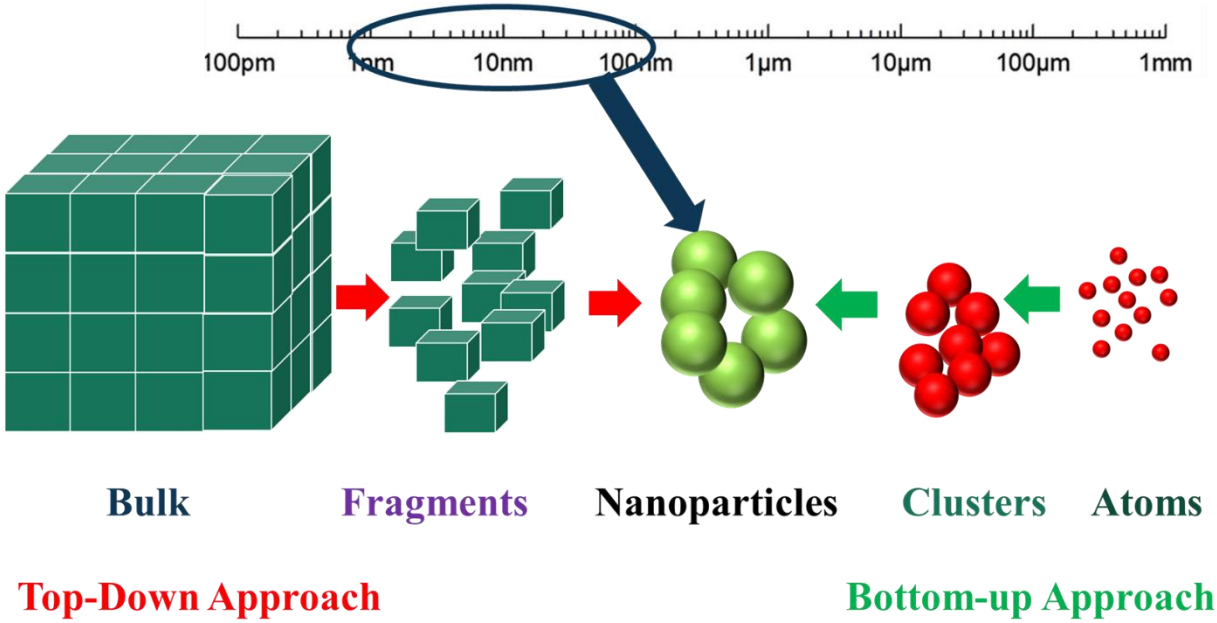


**Figure 1.2** schematic representation of top down and bottom up approach

Metallic nanoparticles are now often produced via a bottom-up technique. The bottom-up strategy entails reducing metallic ions to metal in a condition of zero oxidation. Clustering or aggregation development is an undesirable phenomenon that may be prevented by applying different surfactants or stabilizers [31]. The fundamental idea is to create atoms in a solution that will quickly collapse into nanoparticles, and then use a surfactant to regulate their ultimate size and form [32]. Material science has just recently begun to investigate nanoscience in the 21st century [33]. This field's research and development is quickly expanding over the world. Physical characteristics of nanoscale metallic particles are now being studied in depth [34]. As a result of surface or quantum size effects, these species on the edge between the molecular and solid states have new physical features.

Determining the chemical and physical characteristics of nanoparticles requires a thorough understanding of surface chemistry [35]. Surfactants that generate a covalent connection with metal nanoparticles, for example, can improve nanoparticle stability. Understanding the interaction between the surfactant and the nanoparticle is key to understanding nanoparticle manufacturing and application. There are nearly no qualities that do not change over the surface, yet none of them shift rapidly; instead, they always change slowly or in an oscillatory way over a few atomic diameters. The energy of the atoms on the surface, edges, kinks, and corners of crystallites is greater than that of the atoms in the bulk. Their coordination number reflects the degree of unsaturation of their bonds.

### 1.3.3 Complete classification of nanoparticles synthesis

Various physical and chemical processes are widely utilized to make monodispersed nanoparticles, as illustrated in figure 1.3, and their stability and the usage of harmful compounds in synthesis are of critical concern. The use of hazardous compounds on nanoparticle surfaces and non-polar solvents in the manufacturing process restricts its usage in therapeutic settings. As a result, the development of clean, biocompatible, non-toxic, cost-effective, sustainable, and environmentally acceptable technologies for nanoparticle production is widely sought. However, biological techniques of nanoparticle synthesis utilizing microbes have several disadvantages, such as the time-consuming culture of microorganisms and the difficulties in achieving better control over the size distribution, shape, and structure of nanoparticles.

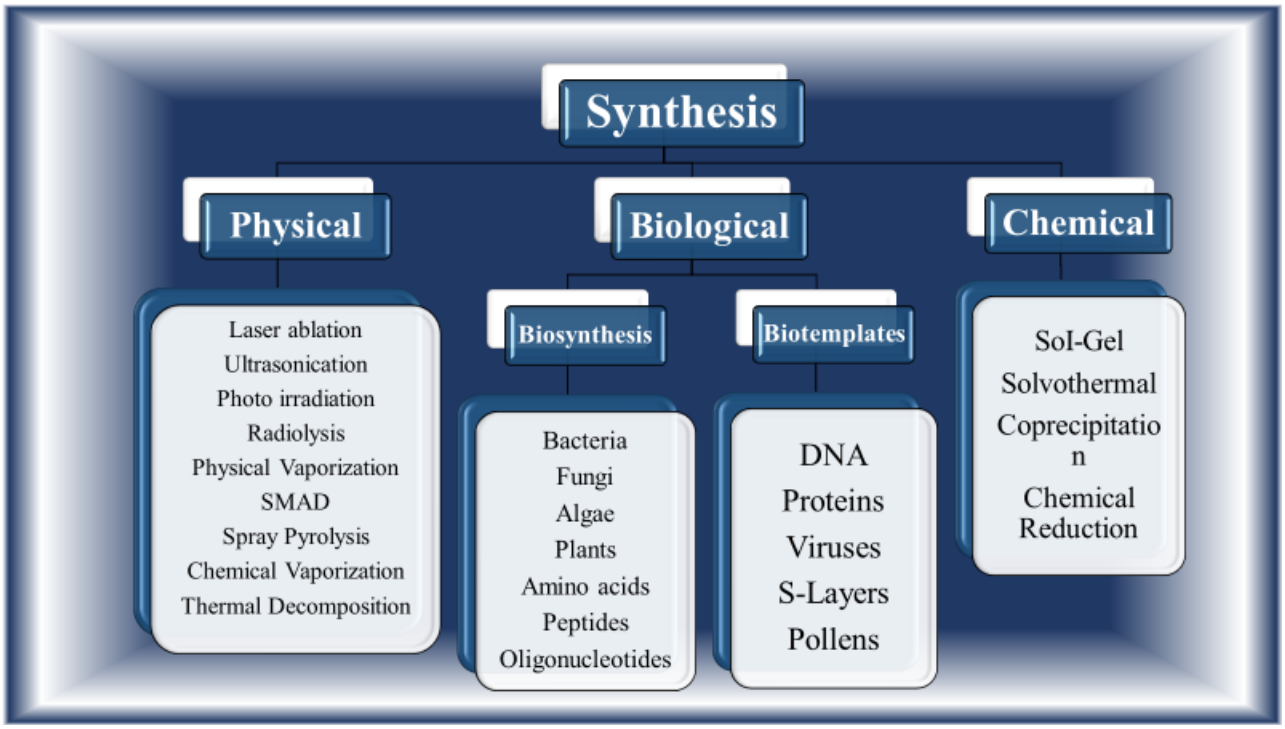


**Figure 1.3** Different routes of nanoparticles synthesis

However, the following are the several nanoparticle synthesis routes:

**Physical Methods of Synthesis of Nanomaterials:**

**Introduction:**

The two main approaches to synthesizing nanomaterials nowadays are top-down and bottom-up. These methods take advantage of large (macroscopic) Greener production of nanoparticles, which is a straightforward, cost-effective, and environmentally friendly procedure that frequently results in more stable materials [36]. Plant-based biosynthesis overcomes some of the drawbacks of utilizing microbes for nanoparticle production, such as sluggish synthesis rates and difficulties controlling sizes and shapes. Fungi are now gaining appeal as nano-factories for the production of nanoparticles all over the world. Overall, biomaterials-based approaches reduce the requirement for harsh and hazardous chemicals, making them a more ecologically friendly or greener chemical technique of producing valuable materials [37]. Plants and plant products, algae, fungus, yeast, bacteria, and viruses are only a few examples of biological resources that might be used to make nanoparticles [38]. Both unicellular and multicellular organisms have been known to produce intracellular or extracellular inorganic materials, but the insights gained from strain selection, optimizing conditions such as pH, incubation temperature and time, metal ion concentration, and amount of biological materials have emerged to give hope in the implementation of these approaches on a large scale and for commercial purposes. It's also possible to make genetically modified microorganisms to regulate the size and structure of nanoparticles [39]. For the synthesis of nanoparticles, a combination strategy such as photo-bio-chemical techniques has proved successful. The Fusarium oxysporum-mediated synthesis of silver nanoparticles, for example, enhances the rate of nanoparticle synthesis. Scientists identified the development of magnetite particles by magneto-tactic bacteria, siliceous materials by diatoms, and gypsum and calcium layer by surface-layer bacteria while investigating the natural secrets for nanoparticle synthesis by microbes. Metal-microbe interactions have been used in a variety of biological applications, including bioremediation, biomineralization, bioleaching, and biocorrosion, in addition to nanoparticle creation. Microbial nanoparticle synthesis has developed as a potential topic of research known as nano-biotechnology, which bridges the gap between nanotechnology and biotechnology. The numerous biological approaches for the manufacturing of nanoparticles are now briefly addressed. In the formation of semiconductor nanocrystals, biological compounds such as fatty acids, amino acids, and polyphates are employed as templates. Various forms of CdSe, CdS, and CdTe nanocrystals may be produced in practice by adjusting the ratio of different fatty acids (chain length).

**1.3.3.1 Algae in nanoparticles synthesis**

Metallic nanoparticles are being synthesized using algae as a bio-factory. Singaravelu et al. [40] used a systematic strategy to investigate the creation of metallic nanoparticles by the algae *Sargassum wightii* recently. This is the first time that marine algae have been employed to synthesize very stable extracellular gold nanoparticles in a short amount of time when compared to previous biological procedures. According to studies, 95% of the $AuCl_4^-$ ions were bio-reduced within 12 hours under stirring conditions. Palladium and platinum nanoparticles were made utilizing their respective metallic chloride salts by the same author.

**1.3.3.2 Bacteria in nano-particle synthesis**

Prokaryotic bacteria have been the most widely studied among natural resources for the synthesis of metallic nanoparticles. The greater simplicity of manipulation is one of the reasons for "bacterial preference" for nanoparticle synthesis. Slawson et al. [41] reported that a silver resistant bacterium strain derived from silver mines, *Pseudomonas stutzeri* AG259, collected AgNPs within the periplasmic region in one of the early experiments in this technique. The particle size varied from 35 to 46 nm in diameter during this experiment. Bacterial nanoparticle production may now be divided into two major categories: intracellular and extracellular synthesis, as discussed below.

**Intracellular synthesis of nanoparticles by bacteria**

Additional processing procedures, such as ultrasonic treatment or interaction with appropriate detergents, are necessary to separate the intracellularly produced nanoparticles. The recovery of valuable metals from mine wastes and metal leachates may also be done using this technology. Metal nanoparticles might potentially be utilized as a catalyst in a variety of chemical processes, which could lead to bioreactor applications. Bacterial activity has been linked to mineral ores deposition in recent years. For iron and manganese oxide deposition, Pedomicrobium or budding bacteria have been found. They have now employed in Alaska placers because they have been discovered to collect gold. *Bascillus subtilus* 168 converted $Au^{3+}$ ions to $Au^0$ and deposited it in 5-25 nm diameter octahedral shape inside their cell walls. Sulfate-reducing bacteria were utilized in gold mines to destabilize gold (l) – thiosulphate complex $(AuS_2O_3)_2^{3-}$ and create elemental gold (<10nm) in the bacterial envelope, which released $H_2S$ as a metabolic end product. Gold was precipitated intracellularly in the periplasmic region of the Fe (III) reducing bacterium *Geobacter Ferrireducers*. Similarly, utilizing the mesophilic bacterium Shewanella algae and $H_2$ as an electron donor, microbial reduction and deposition of gold nanoparticles was performed at 25$^{o}$ C throughout a pH range of 2 to 7 under anaerobic circumstances. Gold nanoparticles with 10-20 nm in the periplasmic space (at pH=7.0) and 15-200 nm on the bacterial surface (at pH=2.8) were formed by the reductive

deposition of gold by the resting cells of S. algae. In the periplasmic region of the bacterium *Pseudomonas stutzeri* AG259, often known as the silver mine bacteria, silver nanoparticles with distinct single-crystal structures such as equilateral triangular and hexagonal with a particle size up to 200 nm have been formed. From silver sulfate ($Ag_2S$) as a base material, these bacteria also synthesized a modest amount of monoclinic crystalline nanoparticles. This method yielded silver and sulfur crystalline nanoparticles in a 2:1 ratio. At a temperature of 30°C and a pH of around 4.5, bio-absorption and bio-reduction of Ag (1) on the cell surface was reported to take about 24 hours for bacteria *lactobacillus sp* A09. Similarly, using the diamine silver complex $[Ag(NH_3)_2]^+$ as the basic material, dried *corynebacterium* SH09 cells formed silver nanoparticles on the cell wall in the size range of 10-15 nm in 72 hours at $60^{o}$ C. Normally, periplasmic silver binding proteins, which bind silver at the cell surface and shield the cytoplasm from toxicity, have effectively negated silver toxicity. The organic matrix is thought to contain silver binding proteins that offer amino acid moieties, which act as a nucleation location for silver nanoparticle production. An airborne *Bacillus sp*. isolated from the atmosphere was recently discovered to decrease $Ag^+$ to $Ag^0$. It has been observed that some bacteria can produce multiple nanoparticles and bimetallic alloys. Nair and Pradeep discovered that *Lactobacillus sp*. in buttermilk created tiny gold, silver, and gold-silver bimetallic nanocrystals with well-defined morphologies within their cell, with no effect on survival. A variety of microbes can synthesize nanoparticles with different morphologies, such as cubic, hexagonal, and spherical, in the size range of 5-200 nm, for example, gold and silver nanoparticles produced by *B. Subtilis*, sulfate producing bacteria, *S. algae*, *P boryanum*, *E. Coli*, *R. Capsulatus*, and others. Absar Ahmad and his research team have conducted a number of experiments on bacterial gold nanoparticle manufacturing. They employed extremophilic actinomycetes called *Thermonospora sp* to efficiently produce monodispersed gold nanoparticles in one of the studies. These researchers employed alkalotolerant *Rhodococcus sp* for intracellular manufacture of high-quality monodispersed nanoparticles in independent investigations [42–47].

**Extracellular synthesis of nanoparticles by bacteria**

The location of the reductive component of the cell affects microbial metal nanoparticle production. When cell wall reductive enzymes are engaged in the reductive process of metal ions, extracellular nanoparticles are a foregone conclusion. Extracellular nanoparticle manufacturing has more applications in optoelectronics, electronics, bioimaging, and sensor technologies than intracellular nanoparticle production. The prokaryotic bacteria Rhodopseudomonas capsulata has been discovered to degrade Ag+3 to Au0 extracellularly at room temperature. When the pH of the solution was kept constant at 7.00, spherical nanoparticles were made, and when the pH of the solution was

changed, nanoparticles of various shapes and sizes were formed. The participation of one or more proteins in the bio-reduction and capping of gold nanoparticles can be shown using polyacrylamide gel electrophoresis (PAGE). Selenium is used in photocopiers and microelectronic circuit devices because of its optical and semiconducting characteristics. Sulfurospirillum barnesii and B. Selenitri are two selenite and selenate respiring bacteria that manufacture stable, uniformly structured elemental selenium (Se0) with a monoclinic crystalline structure [43,48–52] with an extracellular diameter of around 300 nm.

**1.3.3.3 Biosynthesis of nanoparticles by fungus**

Fungi have a number of advantages over other microbes. In comparison to plant materials and bacteria, fungal mycelia mesh can endure flow pressure, agitation, and other conditions in bioreactors or other chambers. Extracellular enzyme secretion is particularly effective in fungi. As a result, large-scale enzyme synthesis is simple to achieve. The economic viability and simplicity of managing biomass are further advantages of utilizing a fungal-mediated green technique for the production of metallic nanoparticles. However, genetic modification of these eukaryotic organisms for the over-expression of certain enzymes poses a substantial challenge to employing these bio-entities in nanoparticle manufacturing.

**I. Intracellular synthesis of nanoparticles using fungus**

When compared to the size of extracellularly reduced nanoparticles, the nanoparticles generated inside the body may be smaller. The size of the particles that form inside the organism is proportional to their size. Mukharjee et al. used verticillium sp. to make gold nanoparticles. The creation of gold nanoparticles with a diameter of roughly 20 nm in the cytoplasm membrane of a fungal mycelium was described in this work. The size and disparity of these produced nanoparticles are clearly characterized. Another fungus, *Trichothecium sp,* was discovered to store gold nanoparticles within its cells. When the fungus Aspergillus flavus was treated with silver nitrate solution for 72 hours, Vigneshwaran et al. discovered that silver nanoparticles accumulated on the surface of the cell wall.

**II. Extracellular synthesis of nanoparticles by fungus**

Nanoparticle synthesis outside the cell provides a number of benefits to nanoparticle synthesis inside the cell. Fungi are commonly thought to be the organisms that create nanoparticles extracellularly due to their large secretary components, which are capable of nanoparticle reduction and capping. Ingale et al. investigated the extracellular mycosynthesis of silver nanoparticles by *F. acumintum* isolated from infected ginger. The spherical shape of these produced nanoparticles was in the region of 5-4 nm. Silver nanoparticles with well-defined shape and stability have been reported to be produced by *Thrichoderma asperellum* in the size range of 13-18 nm [48,53–56].

**1.3.3.4 Virus in nanoparticles synthesis**

Intact biological particles have been used to extend biological techniques to nano-crystal production. The viral scaffolds are said to be able to template the nucleation and assembly of inorganic nanomaterials. Cowpea Chlorotic Mottle Virus (CCMV) and Cowpea Mosaic Virus (CMV) have been employed as nucleation cages for inorganic material mineralization. Tobacco mosaic virus has also been demonstrated to mineralize lead sulphide (PbS) and cadmium sulphide (CdS) to produce crystalline nanowires [57,58].

**1.3.3.5 Yeast mediated synthesis of nanoparticles**

There are just a few instances of metallic nanoparticles being synthesized using yeast. *Candida glabrata* is a eukaryotic bacterium that has been used primarily for the production of semiconductor nanoparticles. Intracellularly, it formed monodispersed spherical-shaped peptide-bound CdS quantum crystallites with a size of 20 $A^0$. By creating metal-thiolate complexes with phytochelatins, it reduced the toxicity of cadmium metal ions. The utilization of yeast for the manufacture of FCC structured PbS quantum nanocrystallites with semiconductor characteristics was initially described by Kowshik et al. Another yeast, *S. cerevisiae*, was discovered to create PbS nanoparticles with a spherical shape and a face center. Antimony oxide ($Sb_2O_3$) nanoparticles with sizes ranging from 2 to 10 nm were shown to have semiconductor characteristics at normal temperature [59,60].

**1.3.3.6 Other biological methods**

Template-assisted synthesis of inorganic nanoparticles and microstructures has employed biological materials such as DNA, protein cages, bio-lipids, viroid capsules, bacterial rapidosomes, S-layers, and multi-cellular superstructures. The creation of nanoparticles is thought to be aided by glutamate and aspartate on the virus's exterior surface. Quantum dot nanowires were created using self-assembled viral capsids from genetically altered viruses as biological templates. With a dual peptide virus-designed capsid, hybrid nano-wires (ZnS - CdS) may also be made [61,62].

**1.3.3.7 Synthesis of nanoparticles using plant extracts**

Techniques for generating nanoparticles utilizing naturally occurring reagents as reductants and capping agents, such as vitamins, sugars, plant extracts, bio-degradable polymers, and microorganisms, might be considered appealing for nanotechnology. Plant-based materials appear to be the best choice among the reagents indicated above, and they are appropriate for the large-scale production of nanoparticles. Metal nanoparticles are made from plant components such as leaves, roots, latex, seeds, and stems. Polyphenols found in tea, wine, winery waste, red grape, and pomace are thought to be the major active agents in certain syntheses. To synthesize nanoparticles from plant extracts, just combine the extract with a metal salt solution at room temperature. Within minutes,

the reaction is finished. This method has been used to make gold, silver, and a variety of other metal nanoparticles. The type of the plant extract, its content, the concentration of metal salt, the pH, temperature, and contact duration are all known to influence the pace of synthesis, quality, and other features of nanoparticles. A leaf extract of Cinnamomum comphora can be used to decrease silver and gold ions and create nanoparticles. The decrease was attributed to the extract's phenolic, terpenoids, polysaccharides, and flavones constituents. At a concentration of $45\,\mu g/ml$, these nanoparticles were shown to exhibit maximal bactericidal action. The presence of H+ ions, NAD+, and ascorbic acid in Desmodium Trifolium extracts was attributed to the reduction of silver ions used to manufacture nanoparticles. The use of Datura leaf extract in the synthesis of very stable silver nanoparticles has been described. Silver nanoparticles made from *O. santum* leaf extract were shown to exhibit strong antibacterial activity against both Gram-negative (*E. coli*) and Gram-positive (*Streptococcus aureus*) bacteria in another investigation. S. Shiv Shankar used *Azadirachta indica* leaf extract to make silver and gold nanoparticles. Tea extracts have been used as chelating, reducing, and capping agents for nanoparticle formation due to the presence of a variety of polyphenols. As a result, the particles formed are shielded from additional reactions and aggregation, increasing their stability and durability. Plant materials that have been employed in nanoparticle production are mainly single pot processes that do not require the addition of extra surfactant [63–65].

**1.4 Biological Effects of Nanoparticles**

Nanotechnology has been widely used in biomedical applications during the last decade, including biological detection, drug delivery, diagnostic imaging, and tissue engineering. As a result of this activity, the diagnostic and therapeutic qualities of these techniques have significantly improved. Traditionally, the primary focus of basic and applied nanobiotechnology has been on cancer diagnoses and the precise destruction of afflicted cell populations. However, as the safety of biomedical nanomaterials improves, as does the accumulation of experimental evidence supporting the benefits of nanomaterial-based agents in terms of selectivity, sensitivity, affinity, and detection limits, Nano biotechnological tools are being used in a growing number of non-cancer applications, including cardiovascular, neurological, gastrointestinal, autoimmune inflammatory infectious, and reproductive diseases. Even if their bulk counterparts are nontoxic, nanoparticles can be harmful in nature. Nano toxicology is the study of nanomaterial toxicity. Toxicity can occur in two ways: first, nanoparticles can activate the human body's immune response system, and second, nanoparticles can behave as a poison. An organism's immune system is a system of biological structure and processes that defends it from disease. To work correctly, the immune system must identify and distinguish a wide range of pathogens, such as viruses and parasites, from the organism's own

healthy tissue. Proteins dissolved in blood and other body fluids adsorb onto the surface of the material and change their structure, generating an immune response triggered by an artificial material (nanoparticle) in contact with blood and tissue. The native protein is thereby converted into a foreign protein, which is recognized as such by circulating immune cells, activating the regular system for removing foreign invaders. Any immovable artificial substance will become an inflamed spot for the rest of your life. The specific biological mechanism is the feature of poison. A poison usually attaches to an enzyme's active site, preventing it from binding its usual substrate. Carbon monoxide, for example, attaches to the heme group of hemoglobin and efficiently outcompetes oxygen binding. The majority of chemicals are non-toxic in their pure state. To prevent the patient from swallowing mercury ions, a bacterium called mercury reductase is used. In three ways, nanomaterials worsen these two possible sources of toxicity. First, when a block of material is split up and dispersed as nanoparticles, the surface area is greatly enhanced. As a result, what may have been a minor immunological triggering becomes a major one. Second, nanoparticles ionize more quickly than bulk metal. The toxicity of lead and silver comes from the detachment and ionization of metal atoms from the substrate block, not from the metal in its elemental form. Finally, because nanoparticles are so small, they can pass through substrates that larger particles would be unable to pass through. Barriers in the human body often take two forms: a lipid bilayer surrounding individual cells and a densely packed layer of cells. There is evidence that nanoparticles can flow between cells stacked in such dense layers as those forming the blood-brain barrier, and that they can pass through the lipid bi-layer into the cytoplasm of single cells in the same way that some macromolecules of comparable size can [66,67].

**2. Role of Nanotechnology in Veterinary Science**

Now let's look at how animals and humans are treated traditionally. On the basis of the patient's symptoms, doctors follow a set of well-defined processes in traditional treatments. The doctor first attempts to diagnose a sick state before deciding whether or not to admit the patient to the ward or outpatient department. The physicians and medical personnel next attempt to collect simple measurements such as temperature, bowel movement, heart rate, blood pressure, and so on. Then, if necessary, doctors will suggest biochemical and microbiological testing such as blood, urine, and sputum tests. The doctor may next recommend internal exams such as X-rays and imaging using modern technologies like as computerized tomographic scans, magnetic resonance imaging, and positron emission tomography ‘‘functional" imaging, if necessary. Molecular testing (gene relocations, increased gene copies, and so on) are done on newborns [68].

**2.1 Use of Nanotechnology in Veterinary Medicine**

According to the traditional view, God has endowed everyone with the ability to heal. Then there's the question of what medicine's job is. In fact, the majority of drugs are created with the goal of keeping patients stable. The process of stabilisation might be helped by surgery or medications. These can be used to reduce the size of tumours or the spread of infectious illnesses. The first and most important stage is to stabilise the patient so that he or she can heal (e.g., intravenous hydration with saline, blood transfusions, simple medicines to lower dangerous fevers). If the patient is unable to do so without assistance, the next step is either surgical repair of damage (reconstructive surgery), removal of sick tissues or organs, or, in the case of nonsurgical procedures, therapy with locally administered chemical medications (e.g., ointments to skins, injection of drugs into tissues or organs). If an issue is more systemic and can't be cured with localised treatments, drugs are given systemically (e.g., chemotherapy). The first versions of these nanomedical techniques are now in restricted clinical trials (for example, nanoparticle albumin-bound paclitaxel) and will be accessible shortly.

They should increase circulation time and targeting, resulting in a reduction in side effects such as neutropenia, which is produced by neutrophils phagocytozing a percentage of the targeted antibodies before they could locate their correct targets.

**Glimpses on Nano-medicine:** Humans have been searching for miraculous cures and treatments for sickness and damage since the dawn of humanity. Nanotechnology uses in medicine, according to several academics, might be the first important step toward the aim. The notion of nanomedicine was proposed by Robert A Freitas as follows:

- It is the molecular-level monitoring, control, building, repair, defence, and enhancement of the (human) biological system utilising manufactured nano-devices and nano-structures.
- It is the science and technology of employing molecular instruments and molecular understanding of the (human) body to diagnose, treat, and prevent illnesses and traumatic injury, relieve pain, and preserve and improve (human) health.
- It is the use of molecular machine systems to solve medical issues, as well as the use of molecular knowledge to maintain and improve (human) health on a molecular level.
- Nanomedicine as a Treatment: Drug delivery and regenerative medicine are likely to be the two areas where nanomedicine will have the most impact. Nanoparticles allow doctors to tailor medications to specific illness sites. This improves effectiveness while reducing negative effects.

**2.2 Introduction of Nanotechnology in Veterinary Medicines:**

Metallic nanoparticles, on the other hand, are affordable and may be used in smaller numbers to promote development and stimulate the immune system. Certain nanoparticles have been shown to aid the fermentation process in the rumen. ZnO has been shown to improve growth rate, immunological response, and cattle reproduction. It can also be used to treat diarrhoea in young piglets. ZnO nanoparticles can successfully cure the diary animal Bos Taurus suffering from subclinical mastitis. By interfering with several proteins involved in antibiotic resistance, ZnO nanoparticles can reduce antibiotic resistance and improve ciprofloxacin's antibacterial efficacy against microorganisms. It's possible that the feed components will oxidise. This can be prevented by utilising nanoparticles to microencapsulate feed components. The encapsulation protects against oxidation and photolysis, as well as digestive enzyme activity.

**Mechanism**

**2.2.1 Anti-microbial Action of Nanoparticles:**

**Antibiotics:** These are chemical substances secreated by some micro-organisms that restricts the growth and development of other micro-organisms.

- Broad spectrum Anti-biotics: These are the substances that control the growth of several unrelated organisms eg. Chroramphenicaol, tetracycline
- Narrow Spectrum Anti- biotics: These are substances that control the growth of few selective number of micro-organisms eg penicillin, streptomycin

  **Penicillins:** This is produced by fungus *Penicillinum notatum* or *Penicillinum crysogenum* and some other species of fungus. This fungus was first of noticed by British doctor and scientis Alexender Fleming in 1928. For the wonderful discovery of Penicilline he was honoured with prestigious Nobel prize in Medicine/Physiology 1945. Penicillines are group of β- lactum antibiotics of related structure with slightly different structures which results in varying properties and activities. All penicillines have a common basic nucleus, a fused β- lactum-thiazolidine ring with different side chains which gives each its unique properties. Different types of Penicillines can be biosynthesized in a single fermentation. Depending upon mode of action antibiotics can be classified into different types as below

A**nti-microbial activity:**

Bacterial antibiotic resistance has been a global concern due to their capacity to cause community-acquired infection. Many techniques to dealing with antibiotic resistance have been proposed. Apart from the proper use of antibiotics for therapeutic and non-therapeutic purposes, researchers have been encouraged to look for safe and effective antibacterial agents. As a result, a variety of inorganic

nanoparticles such as gold, copper, zinc oxide, titanium, and silver have been investigated as antibacterial agents. Silver and its compounds have long been known to have antibacterial properties, and they have been employed as antibiotics to treat infectious infections, burns, and wounds. Because of their large surface area and unique physical, chemical, and biological properties, silver nanoparticles offer antibacterial ability that are superior to the bulk metal. As a result, silver nanoparticles outperform silver compounds like silver nitrate and silver sulphadiazine in terms of antibacterial activity, and are effective against a wide range of bacteria, fungi, and viruses. Silver nanoparticles based on substrates such as mesoporous silica, zeolite, and others; can release silver ions slowly and controllably, making them more effective for long-term antibacterial activity. As a result, silver nanoparticles have a wide range of applications as an antibacterial agent in hygiene, cosmetics, and medicinal applications, as well as antibacterial water filtering. Chlorination has been a prominent way of preventing bacterial development in water, since it was first introduced for disinfection of drinking water at the beginning of the twentieth century. However, because chlorine is a strong oxidant, it combines with organic materials throughout the water treatment process, resulting in a variety of by-products. These by-products may raise the risk of cancer in humans. Furthermore, pathogen resistance to conventional chemical disinfectants necessitates a very high disinfectant dosage, resulting in increased disinfectant by-product generation. However, in developing nations, particularly in rural areas, potable water is typically gathered from untreated sources that are far from home and kept for long periods of time before use, and hence has a lower disinfection capacity at the time of use. As a result, novel disinfection approaches are needed to improve disinfection reliability and efficiency while eliminating disinfectant by-products. The use of silver nanoparticles as an antibacterial water filter has been reported. For antifouling, silver nanoparticles are coated on polyurethane foams, anchored on methacrylic acid as co-polymer beads, and have embedded granular activated carbon and ceramic filter membranes. As a result, materials containing silver nanoparticles are an excellent choice for water purification, especially at the point of use [69,70].

**Mode of action of silver nanoparticles:** The antimicrobial action of silver nanoparticles is not entirely understood, despite various postulated mechanisms. Silver nanoparticles are thought to be a slow-release source of silver ions that react with protein thiol groups and disrupt DNA replication. Furthermore, silver is thought to produce free radicals, which harm the bacterial membrane. Furthermore, antibacterial activity may be induced through direct contact between a nanoparticle and a bacterial cell, resulting in structural damage to the cell wall.

**2.2.2 Nano-nutrient:**

Nano nutrition is a science that studies nano nutrients from various perspectives, such as uptake, translocation, metabolism, and bioavailability of nano nutrients in the rhizosphere for plant growth and development, or nanotechnology applications for the provision of nano nutrients for crop production. Plant nano-nutrition is described as the use of nanoparticles or nanomaterials in plant nutrition. It entails applying these nano fertilizers or nano nutrients to farmed plants in order to provide them with the nutrients they require for growth and productivity (e.g., ZnO, SiO2, iron oxide, CuO, Mn oxide, phosphorus, nitrogen nanoparticles, etc.). Nano nutrients, as previously said, are nutrients with nano-dimensions ranging from 30 to 40 nm and the capacity to contain numerous nutrient ions due to their large surface area; the release of nutrients is gradual and steady in accordance with crop demands. A few studies have also reported on the impact of nano nutrients on crop nutritional quality. Plant nano-nutrition is a branch of plant nutrition concerned with the nutrition and growth of plants through the use of nano nutrients or nanoparticles. These Nano nutrients have a good impact on agricultural plant development as well as nutritional quality. There are undoubtedly certain limitations in plant Nano nutrition, notably in the large-scale and worldwide use of these Nano nutrients. The many interactions between Nano nutrients or nanomaterials and various agroecosystem compartments are yet unknown, and further study is needed [71]. Nanotechnology has recently focused on the detection of plant illnesses, plant disease management, and the production of Nano nutrients for plant growth improvement. Few studies, on the other hand, have demonstrated that some designed nanoparticles can help plants grow faster by modifying their metabolisms. The toxicity of nanoparticles to microbial biomass, plant growth-promoting bacteria, Pseudomonas fluorescents, cell lines, Chlorella pyrenoidosa, maize seed germination, and plant phytochemicals has recently been the subject of a number of studies [72].

**Nanotechnology in the Diagnosis of Diseases**

The sickness of an animal cannot be understood in veterinary medicine unless clinical indications are seen. Until the sickness is discovered, the infection can spread quickly across the herd. Nanotechnology has the same scale of action as viruses and diseases (infected particles), hence it has a unique potential for early detection and therapy. Because of this feature, nanotechnology may be a helpful tool in important clinical diagnostics.

**Nanotechnology for treatment**

For pet owners and the government, veterinary health care is a highly visible and developing problem. Given the rising expenses of drugs and veterinary care, as well as the growing pet population, creative solutions are critical. The efficient distribution of therapeutic compounds has

been a key roadblock in achieving a focused response to the disease agent. Many medications are useful at treating illnesses, but they all have drawbacks, such as toxicity, low water solubility, and cell impermeability. Therapeutic and diagnostic agents are at the forefront of nanomedicine efforts, with research focusing on medication delivery and targeting in animals. Nanopharmaceuticals are the most promising and fruitful field of nanotechnology use in animal therapy because nanoparticles have a greater intracellular absorption than microparticles and are thus available for a wider variety of biological targets due to their small size and increased mobility. Polymeric nanoparticles, carbon nanotubes, liposomes, dendrimers, nanoshells, nanopores, magnetic nanoparticles, and other nanomaterials are employed in the treatment of veterinary disorders. The key problem is to use the above-mentioned nanomaterials to create different revolutionary devices and technologies that will allow treatments to be guided to their precise region of action and will ensure that pharmacological activity is sustained for an acceptable period of time.

**Nanotechnology and drug delivery to animals**

In nearly every example, nanotechnology has been used to deliver drugs to experimental animals, particularly mice. The majority of these applications, however, have little relevance to veterinary medicine because they are part of human illness research. In addition to nanotechnology-based medication delivery methods, nanotechnology-constructed pharmaceuticals should be included. Soybean oil emulsified with detergents to generate nano-drops is arguably one of the most promising chemicals in this category. Because of their incorporation into the viral envelope or the microbial cell membrane, they are utilised as non-selective microbiocidal agents. Because it can induce rupture of host non-nucleated cells, such as sperm and erythrocytes, the specialised nano-therapeutic extract has no physical impact on nucleated cells, which limits its usage to surface wounds. However, because their erythrocytes are nucleated, this might be a "window of opportunity" for veterinary medicine in relation to fowl or fish, which could be an appropriate model for an application that would circumvent the particular constraint.

**Chitosan in drug delivery:**

We earlier reported that, as a polymeric drug carrier, chitosan (CS) is used. Chitosan, a poly-aminosaccharide, is often made by alkaline deacetylation of chitin, the main component of living creatures like fungi and crustaceans illustrated in fig. 2.1. Chitin may be discovered in the exoskeleton and interior structure of shrimp and crab shells. Chitosan has shown therapeutic effects in the areas of cholesterol reduction, wound healing, antiulcer, and antibacterial properties, and it is commonly utilized as a polymeric drug carrier in microcapsules [73]. Furthermore, here we discuss applications of chitosan in drug delivery. A new PLGA-based drug delivery system with active and

adaptable surfaces is created in this work. The zeta potential of chitosan-modified PLGA nanoparticles reduced drastically as the pH value raised, indicating that they have a positive charge surface. The drug release profile was influenced by the presence of chitosan on the surface of PLGA nanoparticles [74].

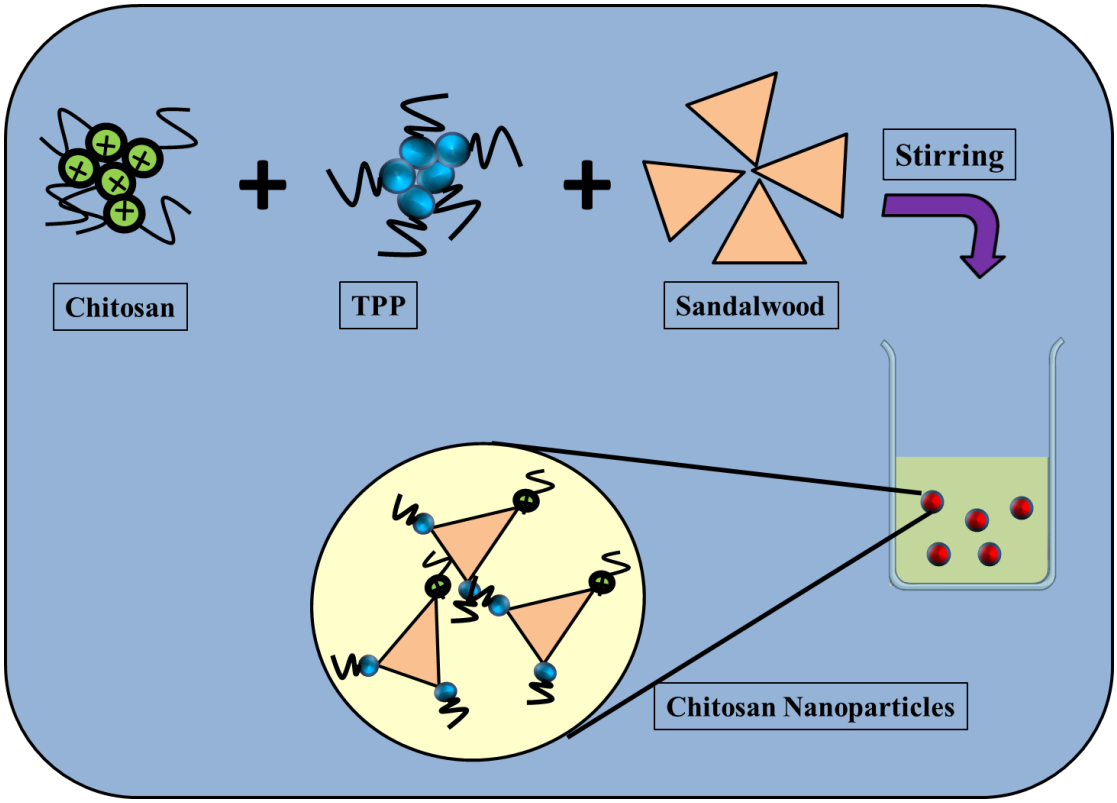


**Fig. 2.1:** Chitosan nanoparticles for drug delivery.

Applicability of this novel vaginal drug delivery formulation, which contains 2.5% w/w chitosan gel as the vehicle and polymeric nanocapsules. When compared to the free medication, the chitosan gel and polymeric nanocapsules enhance mucoadhesion and the quantity of lipophilic drug that penetrates into the tissue, perhaps leading to a higher impact. The novel formulation can be considered as an alternative for treatments that require the drug to remain in contact with the mucosa for an extended period of time, as well as treatments that require the drug's adverse effects, such as mucosa irritation, to be reduced, which nanoencapsulation can accomplish [75]. Optimal crosslinking material for encapsulating neem seed extract was successfully carried out in an ultrasonication-wave environment, providing nano-sized capsule particles with remarkable accuracy. AI's tolerance to UV radiation and pH fluctuations is improved by the encapsulation approach. The insecticide potential of the neem seed extract/chitosan nanoencapsulation produced

is evaluated based on the fraction of Riptortus linearis mortality. The bioassay experiment shows that neem seed extract/chitosan has more anti-feeding capabilities than neem seed extract, even at larger doses, leading to the conclusion that encapsulation improves the insecticide's impact. It kills pod-sucking bugs more effectively. This research indicates that encapsulation is a viable method for increasing the efficacy of neem seed extract as an organic insecticide [76]. Bulk Mixing (BM) and micro fluidic (MF) procedures were used to successfully manufacture two types of chitosan-based nanoparticles carrying anti-acne medicines. When comparing the MF chitosan nanoparticles 0.05 sample to the BM chitosan nanoparticles sample, the performance assessments indicated that the MF chitosan nanoparticles 0.05 sample has a consistent morphology and a smaller mean diameter size. In vitro drug release tests revealed that nanoparticles produced using the MF technique exhibited a sustained regulated release of Clin and Tre medicines. The samples' long-term thermal stability demonstrated that MF chitosan nanoparticles samples were more resistant to drug degradation over the course of a month. The animal model trials on rabbit and rat skins showed that utilizing nanoparticles carrying medications did not cause skin irritation or erythema, and that these nanoparticles could pass through the skin layers and treat acne spots due to their tailored average size. Finally, using these microfluidic-assisted nanoparticles based on CS, our study work possibility may be used to the field of transdermal drug administration [77].

**Dendrimer**

As earlier reported by our group dendrimers are nano-sized hyperbranched molecules, with homogeneous and monodisperse structure (shown in fig. 2.2) and it can also change its size and shape. The dendrimers has the applications in the field of Drug delivery, diagnostics, anticancer therapies and in the field of biomedical for example, poly-amidoamine dendrimers is used as blood substitute [73]. Dendrimer contains various functional groups, nucleus and internal layer consisting of repetitive units. The nucleus encapsulates different types of molecules and defines the shape of particle. Small molecules carried by the second layer of repetitive unit, and each single branch is named as “generation”. The peripherical functional groups which are enclosed in the environment act together. For the large synthesis of inorganic and organic nanostructures with dimensions of 1-100 nm, they are the necessary tools. In the pharmaceutical industry dendrimers are used to manufacture high-performance drug discovery products, for instance antivirals, non-steroidal anti-inflammatory formulas and antimicrobial medication. Dendrimers have average diameters ranging from 10 to100 nm and used to deliver drugs. Some organic structures are attached to their surface, such as DNA [78].

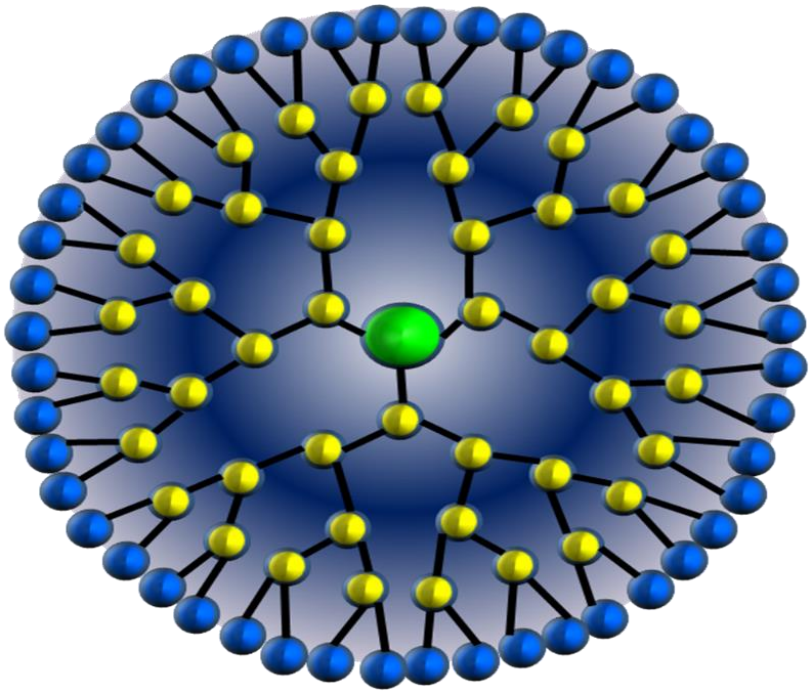

**Fig. 2.2** Dendrimer Nanostructure

For the dendrimers, the attachment of different kinds of molecules is possible and this property is widely applicable in drug delivery. Basically, dendrimers have large empty space between flexible divisions and the drug can be trapped between that empty spaces. The encapsulation was made by this dense structure. It is practically possible to create these well controlled building blocks and it has variety of uses in drug distribution and cancer treatment. Dendrimers are useful in drug delivery because they transport drugs at a precise rate due to chemical modulation, as well as changes in hydrolytic release conditions and a selective steady flow of drug molecules based on their size or form. Dendrimers with large amount of drugs shows very fast pharmacological reactions with high efficiency [79]. Antimicrobial and anticancer drug delivery, vaccination, gene transfer, and MRI imaging were all examined with this type of particle, although only a few efforts dealt with anthelmintic drugs. It is suitable for nanocarriers because it is cheap and also has some properties like high solubility, cell membrane trespass and tuning capability. In this field 1$^{st}$ research was focused on polyamidoamine (PAMAM) and it is confirmed by ammonia or ethylenediamine nucleus. The shape of PAMAM is very similar to the insulin or hemoglobin. Later on, more dendrimer groups arose, such as polipropilenimine (PPI), tecto, multilingual, chiral, amphiphilic, and micellar dendrimers, all of have distinct physical and chemical properties that confer precise scope. Combinations of dendrimers and anthelmintics are uncommon. In vitro, a PAMAM-albendazole attached structure enhanced the drug's solubility, indicating that PAMAMs could develop the drug absorption in vivo. Likewise albendazole oral tables use a fifth generation PPI

dendrimer anchor to chitosan (muco-dendrimer). In a murine model, this formulation increased the half-life and mean residence time of albendazole as compared to the free drug. PAMAM was also utilised to increase the solubility of niclosamide, a salicylanilide anthelmintic in water used to treat cestodes and trematodes. The authors discovered that not only did the drug have a higher solubility, but also has the strong interaction between the niclosamide and amine functional groups of PAMAM resulted in a longer drug release [80].

**Nanobottles**

Colloidal particles with a hollow interior and a single opening in the wall are referred to as nanobottles (fig.2.3).

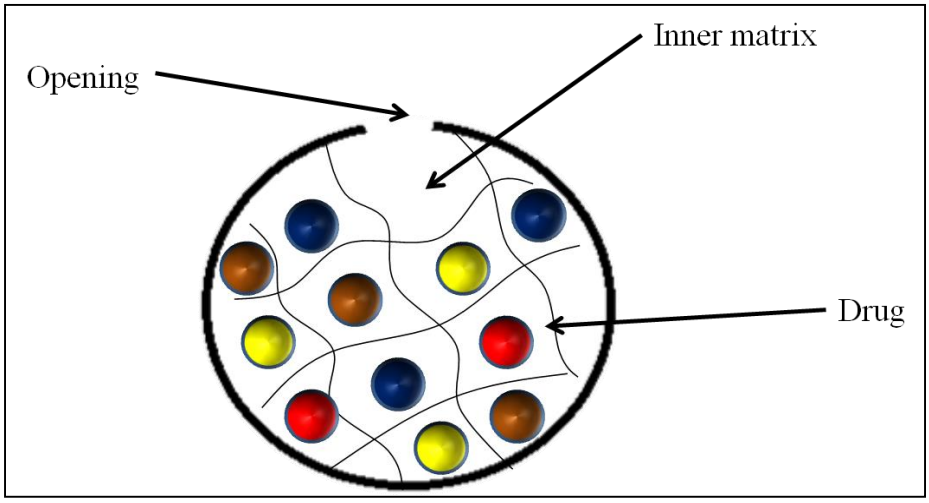


**Fig. 2.3 Nano bottles for Drug Delivery**

They are appropriate carriers for the loading, encapsulation, release, and transport of numerous types of theranostic drugs in a variety of biological applications due to their unique properties. They have a large loading capacity because to the hollow interior, and the entrance allows for fast loading and controlled release of the payload. More importantly, introducing a stimuli-responsive material like the inner matrix or cork stopper can easily enable on-demand release. This progress report begins with an overview of nanobottle architectures and attributes, followed by a discussion of the fabrication methods that have been developed. The utilisation of nanobottles to carry various payloads, such as small-molecule medicines, biomacromolecules, imaging contrast agents, and functional nanoparticles, is then demonstrated. The methods for altering the size of the opening and/or integrating with a stimuli-responsive material to control the release are also addressed [81].

**Graphene Oxide**

In vivo cancer treatment with graphene has recently been demonstrated in animal tests. PEGylated nano-graphene oxide (N-GO-PEG) with ultra-small diameters (10–50 nm) and great stability in

physiological solutions was created by functionalizing graphene oxide (GO) with amine-terminated branching PEG (Polyethylene glycol). The graphene surface with delocalized electrons can be used for successful loading of aromatic anticancer drugs such as doxorubicin and water-insoluble SN 38 via π-π stacking, similar to drug loading on CNTs. With every atom exposed on its surface, graphene's extraordinarily wide surface area allowed for extremely high drug loading efficiency on NGO-PEG. The terminals of PEG chains could be used to conjugate targeting ligands like antibodies, allowing for tailored medication delivery to certain cancer cell types. Furthermore, GO was discovered to have NIR photoluminescence. Nano-graphene oxide NIR photoluminescence was used for selective imaging of cancer cells in vitro, despite its weakness. GO, like CNTs, had a high NIR optical absorption that was considerably improved after chemical reduction. The reduced GO was used to target cancer cells for NIR photothermal treatment in vitro while maintaining biocompatibility. Aside from delivering small drug molecules, recent research revealed that functionalized graphene sheets could also be used to transfect genes [82].

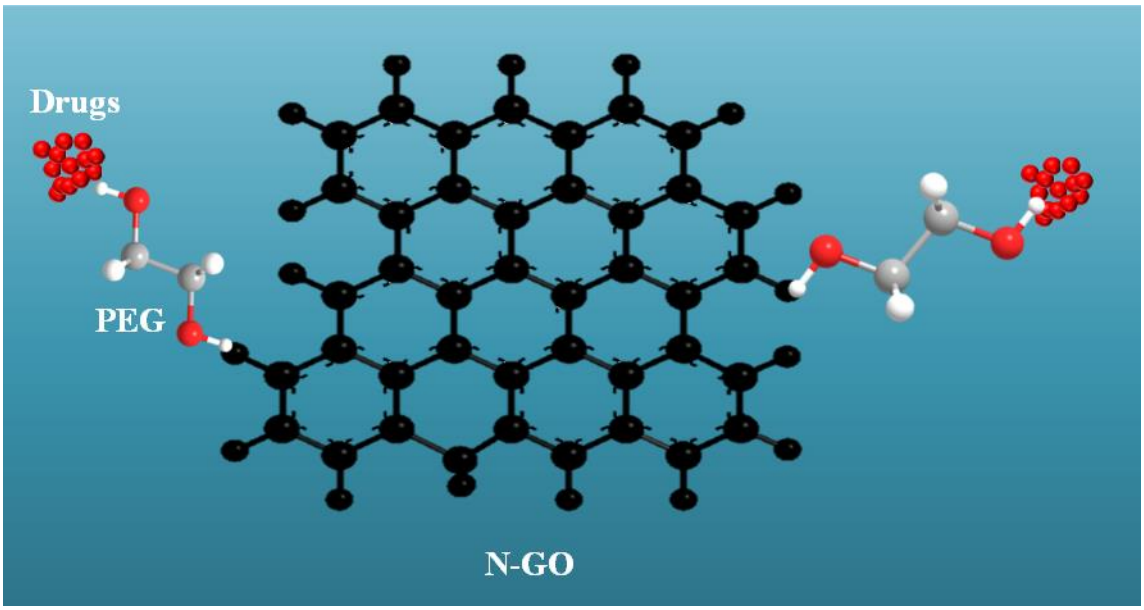


**Fig. 2.4 Graphene oxide for Drug Delivery**

**PROTEIN NANOPARTICLES**

Protein-derived nanomaterials, particularly protein nanoparticles, are biodegradable, non-antigenic, metabolizable, and can be easily modified and covalently attached to medicines and ligands. Protein-based nanoparticles may indicate multiple possibilities for surface change and covalent drug attachment due to the defined fundamental structure of proteins. Protein nanoparticles can be integrated into biodegradable polymer microspheres/nanospheres for controlled release depot or oral delivery, or they can be used for pulmonary delivery of protein therapeutics.

**1. Gelatin**

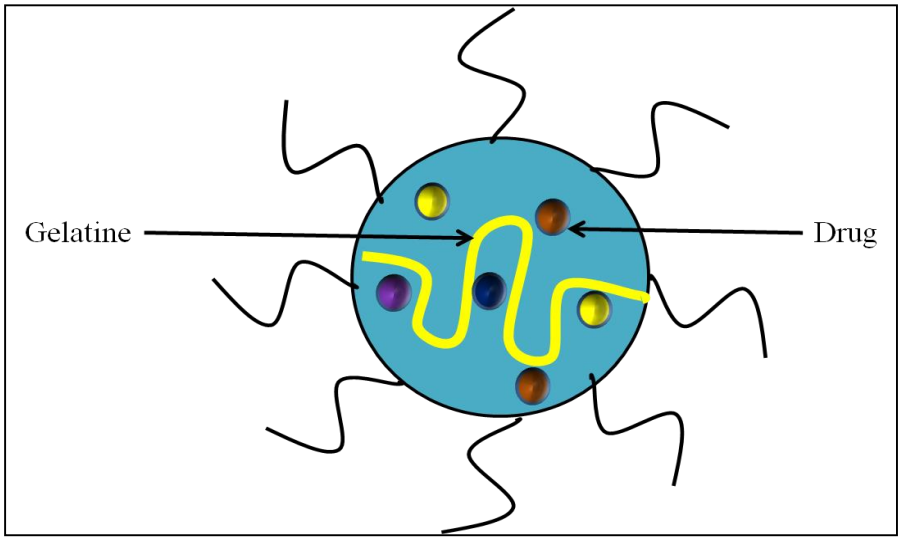


**Fig. 2.5 Gelatin Nanoparticles for Drug Delivery**

One of the protein materials that can be utilised to create nanoparticles is gelatin. Collagen, a fibrous, insoluble protein that is frequently found as a key component of skin, bones, and connective tissue, is generated through controlled hydrolysis. Gelatin's main structure allows for a wide range of chemical modifications and covalent drug attachments. This can be done either within the particles' matrix or only on the particle surface. In the first case, gelatin macromolecules must be chemically modified before nanoparticles can be created, whereas in the second situation, the particle surface is exploited. Gelatin-based nanoparticles are a promising carrier system for drug delivery because of these features, as well as the tremendous potential of nano-sized delivery systems.

**2. Albumin**

Because of its availability in pure form, biodegradability, nontoxicity, and non-immunogenicity, albumin is a popular macromolecular carrier for nanospheres and nanocapsules. Human Serum Albumin (HSA) and Bovine Serum Albumin (BSA) have both been employed.

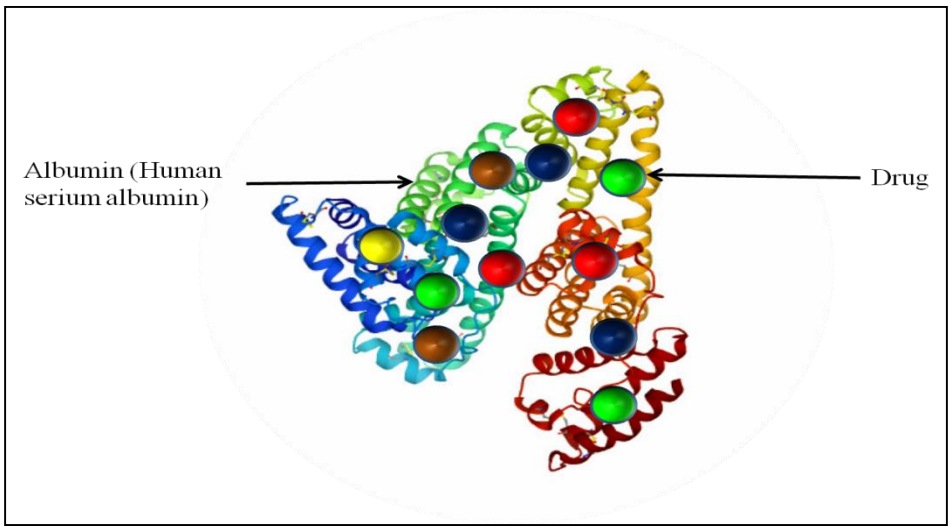


**Fig. 2.6 Albumin Nanoparticles for Drug Delivery**

Albumin has a significant advantage over other materials for nanoparticle formation because it is a prominent plasma protein. Albumin nanoparticles, on the other hand, are biodegradable, easy to prepare in defined sizes, and have reactive groups (thiol, amino, and carboxylic groups) on their surfaces that can be used for ligand binding and/or other surface modifications. In addition, ligands can be easily attached by covalent linkage to albumin nanoparticles. Proteases can breakdown drugs contained in albumin nanoparticles, allowing drug loading to be measured. Albumin accumulates in solid tumours, according to a number of studies, making it a possible macromolecular carrier for anticancer drug delivery [83].

**Bio-technology and vaccine delivery to animals**

Vaccination, in its basic idea, tries to replicate the development of naturally acquired immunity by inoculating pathogens or closely similar organisms with non-pathogenic but nonetheless immunogenic components. Animal and veterinary vaccines might have quite different criteria than human vaccines. A vaccine is a biological preparation that boosts resistance to a specific illness. The word vaccination comes from the Latin word vacca, which means cow. Vaccines can serve as both preventive and therapeutic purposes. The rabies after bite vaccination is an example of a therapeutic vaccine. A vaccination contains an antigen that looks like a disease-causing bacterium and is frequently manufactured from heat-killed microorganisms. The vaccinations might be used to assist manage, remove, or eradicate an illness at the population level, as well as to avoid clinical indications of disease following infection. The vaccine's mechanism of action may be described as an agent that causes the body's immune system to detect the agent as foreign, kill it, and retain a record of it. As a result, the immune system can better recall harmful microbes and eliminate any of them that it meets later. If we look back at the history of the vaccination, Edward Jennar deserves credit. Dairy

employees, he noted, would never contract the sometimes-deadly illness smallpox. This is due to the fact that they already have cowpox, which has a slight effect on humans. He continued his research to validate this. He collected pus cells from a cowpox-infected milkmaid and implanted them in the arm of an eight-year-old child. Six weeks later, the youngster was injected with smallpox, but he did not develop the disease. Louis Pasteur was the next to make a significant contribution to the field of vaccines. He might be able to create vaccines for poultry cholera and anthrax.

The vaccination may be divided into several categories, as shown below:

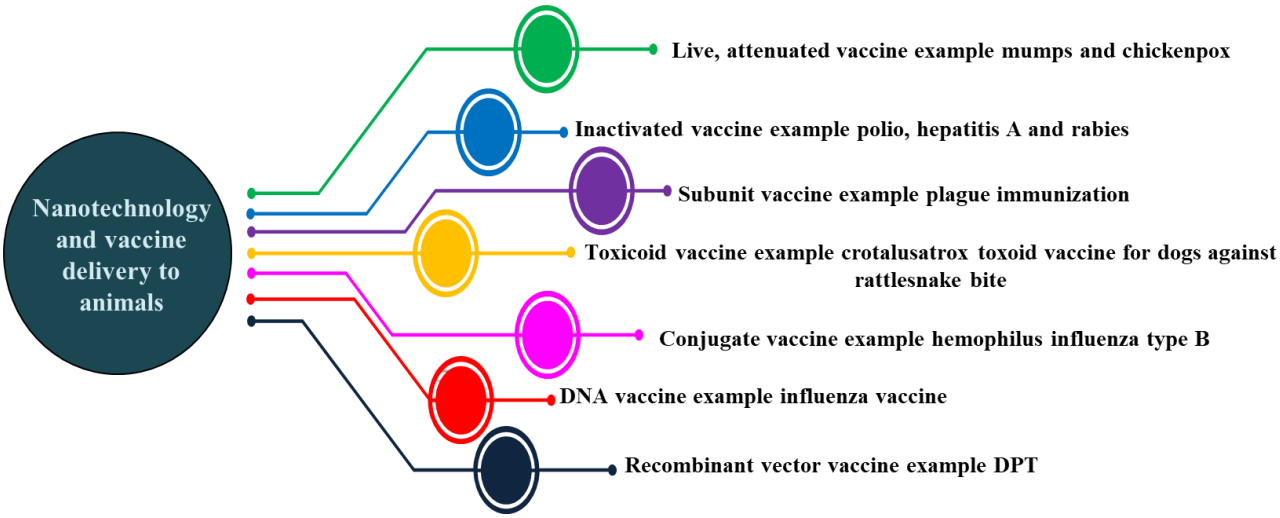


**Fig. 2.7** Use of Nanotechnology for vaccine delivery to animals

**Livestock Vaccine**

Climate change, in combination with other variables such as increasing human and animal migration, creates a new and fast-moving cattle disease pattern. Vaccines are also required in nearly every cattle breeding scheme. Nearly 35 years ago, gene technology was launched. It has been discovered that 17 of the 25 main human illnesses are zoonotic, and that 65 percent of the 1500 human infectious diseases are zoonotic. Immunity refers to a person's ability to resist or be immune to a certain disease. Immunity is a state that allows for either natural or acquired resistance to illness. In the presence of antigen, a cell's ability to react immunologically. There will be few lymphocytes with specialised receptors during the body's first interaction with a virus. It takes time for cells to divide and create clones, for B lymphocytes to release antibodies, and for T lymphocytes to produce T lymphocytes. If the same virus attacks again, memory cells can respond faster and more effectively. Vaccines can include live or dead organisms, as well as purified antigens from these species. The best protective response is elicited by vaccines that include live organisms. Because they can't proliferate and disseminate in the host, killed organisms or purified antigens may be less immunogenic than living

ones. As a result, they are less likely to boost the immune system optimally. They are, however, expected to be safer and more cost-effective [84,85].

**Active immunity**: Naturally acquired immunity

Artificially active immunity

**Passive immunity**: Naturally acquired passive immunity

Artificially acquired passive immunity

**Natural Immunity Active and Passive**

Natural immunity can be acquired by infection. It's known as active immunity. This is due to the fact that the body must operate in order to develop the required antibodies. When a woman breastfeeds her child, antibodies are passed on to the child. This is how passive immunity is obtained. This is due to the fact that the newborn acquires antibodies without making them. Antibodies and stem cells abound in the thick yellowish milk produced a few days after delivery.

**Artificial Immunity Active and Passive**

Vaccination is an alternative to natural immunity development. Antigen is injected into the body here. This might be in the form of inactivated bacterial toxins or a non-harmful (attenuated) virus that promotes active immunity. Antibodies or antitoxins are injected into the body to boost passive immunity.

A**ttenuated Viruses and Bacteria Causes Immunity Without Diseases**

The inclusion of a live organism in a vaccination has a number of benefits. For example, when it comes to activating a cell-mediated immune response, they are typically more effective than inactivated vaccines. Microorganisms can be attenuated in some situations, losing their ability to cause major disease (pathogenicity), while retaining their ability to thrive transiently without an inculated host. Growing a harmful microorganism for a long time under aberrant culture conditions might result in attenuation. Historically, attenuation has entailed adapting organisms to grow in strange environments. This method chooses mutants that are better suited for development under aberrant culture conditions and hence have a lower proliferative capacity in normal host cells. Scientists, for example, created an attenuated strain of Mycobacterium bovis. This strain was created in a medium that gradually increased the content of bile. This strain could be cultivated in concentrated bile after 13 years and was shown to be an efficient TB vaccine. Vaccines that have been attenuated offer both advantages and downsides. Attenuated vaccines enable longer immune system exposure to specific epitopes on attenuated organisms due to their potential for transitory growth, resulting in improved immunogenicity and memory cell formation. As a result, such vaccinations only require one inoculation and do not require booster doses. Many attenuated

vaccines have the potential to reproduce within host cells, making them ideal for generating a cell-mediated response. When it comes to veterinary viral vaccines, the majority of them cause minor infections with live organisms originating from non-target hosts or attenuated by passing through various cell line cultures of chicken embroys. These vaccines can proliferate and produce both cellular and humeral immunity without the need of an adjuvant since living organisms can infect target cells [86,87].

**Classification of Common Human and Livestock Vaccine:**

**Table 1:** Common Human and Livestock disease, vaccine and inventor

| Serial No | Disease | Name of Vaccine | Inventor |
|---|---|---|---|
| 1. | Anthrax | anthrax vaccine adsorbed (AVA) | Louis Pasteur |
| 2. | Cholera | Inactivated | Waldemar Mordecai Haffkine |
| 3. | Pertussis | DTaP and Tdap | Dr. Pearl Kendrick |
| 4. | Black Quarter | Black Quarter | Louis Pasteur |
| 5. | Rinderpest | Tissue Culture Rinderpest Vaccine (TCRV) | Walter Plowright |
| 6. | Foot and Mouth Disease | FMD vaccine | Friedrich Loeffler |
| 7. | Plague | EV NIIEG | Waldemar Mordecai Haffkine |
| 8. | Tuberculosis | bacillus Calmette-Guérin (BCG) | French bacteriologists Albert Calmette and Camille Guérin |
| 9. | Typhoid | Ty21a and Vi capsular polysaccharide | British pathologist Almroth Wright |
| 10. | Hepatitis A | Havrix, Vaqta | Maurice Hilleman |
| 11. | Influenza | Fluzone® High-Dose | Jonas Salk and Thomas Francis |
| 12. | Measles | MMR vaccine | Maurice Hilleman |
| 13. | Mumps | MMR vaccine | Maurice Hilleman |
| 14. | Rotavirus | Maharaj Kishan Bhan | RotaTeq® (RV5) |
| 15. | Rubella | Meruvax II | Dr. Stanley Plotkin |
| 16. | Vericella zoster | Zostavax, Shingrix | Dr. Michiaki Takahashi |
| 17. | Yellow fever | Yf-Vax | Max Theiler |

**Some recent developments:**

New vaccinations are being developed in Taiwan using a DNA vaccine with an encoded target gene. These studies revealed that DNA vaccines regularly elicited an antibody response and were toxin-resistant. Other benefits include protection from illnesses for which there is presently no vaccination. They don't require any harmful infectious agents to make them. Korean scientists have produced a new form of vaccination that is effective against pleuropneumonia, pneumonic pasteurellosis, and enzootic pneumonia, three swine illnesses. A better vaccination to protect pigs against swine fever has been developed using molecular biology. A better vaccination against haemorragic septicemia for water buffalo and cows has been developed in the Philippines. This new vaccination is affordable and provides enough protection for the animal. In addition, better vaccinations for birds have been developed to protect them from Newcastle disease, chicken cholera, and infectious coryza. Adjuvant and antigen are combined in the vaccine, which produces a long-lasting and protective antibody response. The traditional vaccination technique of using live and dead organisms has been replaced by the use of safe synthetic and recombinant vaccines. These novel vaccines are often susceptible to degradation and have low immunogenicity, necessitating the use of an adjuvant with increased immunogenicity. Traditional adjuvants cannot be controlled, but nanotechnology has led to the creation of a variety of novel antigen delivery techniques. This trait allows it to be utilised in the case of non-application at the same time or when typical vaccination procedures are cumbersome in species with high animal numbers. Nanoparticle adjuvants boost vaccination immunity by mimicking pathogen molecular models, allowing for the modulation of co-stimulatory molecules on antigen-presenting cells, immune system maintenance, and long-term antigen delivery. Nanoparticles can be engineered to produce virus-like particles with morphologies comparable to viral capsids that elicit immune responses rather than causing infection.

**Nano-medicinal risks**

Scientific uncertainty about the harmful properties of nano-particles complicates and hampers the implementation of regulative measures by legislators. The European Commission has adopted an “incremental approach”, which focuses on adapting existing laws to regulate nanotechnologies. Humans can be at risk due to nano-particles exposure. The literature indicates that orally delivered nano-particles have the ability to be absorbed through the intestine and translocated to different organs in the body. In spite of significant efforts by research groups and many companies to elucidate toxicity questions surrounding nano-particles, there are no confirmations about the safety of the products to become available on the market across the board. The special physiochemical properties of nano-medicines raise several critical considerations: 1) nano-particles reverting live vaccines back

to their virulent form and/ or making vaccines unstable; 2) potential transfer of antibiotic resistance to humans or animals via the food or feed supplies; 3) disposal procedures of the residual of nano-vaccine, bactericidal packages, vials and dead animals; 4) potential immune or other toxicity in consumers. High doses of nano-particles could affect the organs and tissue of the animal; the effect is a function of nano-particle composition. For example, harmful effects of high doses of nano-silver on the liver cells in broilers. However, it is not well known which portion of toxicity is due to the nano-form and what is resulting from the ionic form. So, nano-silver might be used as an antimicrobial agent or disinfectant in the poultry industry only with caution and under specific conditions to avoid toxic effects in animals. Moreover, toxicity studies on the long-term exposure to some nano-particles showed several effects on the immune system and that the nano-particles could be distributed in animal and human organs e.g. liver and spleen. For improved safety and enhancing the use of nano-particles, biodegradable nano-particles should be designed and more effort dedicated to determining their intracellular fate and biological interaction and function in order to provide safe nanoparticle drug delivery systems for use in animal systems [88–90].

**Nano-hazards to animal-human food chain**

Scientists, stakeholders and manufacturers have already identified potential uses of nanotechnology in every segment of the food chain, particularly in food processing. For instance, The Organization for Economic Co-operation and Development (OECD) reported that notifications for food nano-applications had been received by the Food Packaging Materials and Incidental Additives Section of Health Canada. On the other hand, there may be potential risks to consumers due to consumption of animal products nano-materials in their food. From a physiological perspective, new properties of nano-particles may enable them to reach those parts of the body which are protected from entry of any exogenous materials. Found a relationship between the size of nano-particles and its effect on the human cell. They reported that smaller silver nano-particles (5 and 20 nm) have a deleterious effect on the human cell morphology and its membrane integrity. Moreover, ultrastructural observations confirmed the presence of silver nano-particles in the cells. mentioned that when nano-silver particles pass the physiological barriers and reach the systemic circulation, the particles can interact with plasma proteins and other blood components such as red and white blood cells [91]. Moreover, they may be distributed into organs such as liver, kidney, heart, brain, lung and testicles via the systemic circulation. Poly lactic-co-glycolic acid (PLGA)nano-particles have the ability to translocate from the intestine, especially to liver, kidney and spleen with minimum toxic effects in these organs, as determined by histological evaluations of this tissue [92].

## 2. CONCLUSION

Nanoscience and nanotechnology are a new field of science and technology. At the nanoscale, the materials acquire novel features. Such features can be useful in a variety of industry and medical fields. We investigated the notion of nanoparticles, changes in characteristics at the nanoscale, and probable explanations for these changes in properties at the nanoscale in this review work. We've also looked at the many approaches and classifications for fabricating materials at the nanoscale. The notion of nanotechnology has also been observed in veterinary care, notably in medication delivery and vaccines. Finally, we attempted to address the idea of immunity as well as the hazardous consequences of nanoparticles.

## ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

## HUMAN AND ANIMAL RIGHTS

No Animals/Humans were used for studies that are base of this research.

## CONSENT FOR PUBLICATION

Not applicable.

## AVAILABILITY OF DATA AND MATERIALS

The author confirms that the data supporting the findings of this research are available within the article.

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## CONFLICT OF INTEREST

There are no conflicts of interest to declare.

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