

# Chapter 13

## Advancement of Nanocarrier-Based Engineering for Specific Drug Delivery for Cancer Therapy



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**Abstract** Cancer has progressed to distant organs and is becoming increasingly resistant to chemotherapy; advanced carcinoma is still thought to be an incurable condition. Even though significant therapeutic advances and more efficacious medicines have been made in recent years, long-term incidence rates and unwanted side effects remain the most significant downsides of current clinical procedures. Furthermore, because the majority of chemotherapy medications are hydrophobic,

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they must be diluted in organic solvents that are poisonous, in order to get an appropriate therapeutic dosage. Because of the limits of traditional cancer treatments, nanomedicine, or the medical use of nanotechnology, has been developed to give more safe and effective treatment for cancer. Nanomedicines' ability to overcome resistance, increase solubility, enhance pharmacological character, and lessen chemotherapeutic medication side effects is so highly appreciated. During the last decade, their application in therapeutic settings has risen. At the moment, investigation is being conducted in the domain of innovative nano-pharmaceutical technology, including liposomes, polymer nanoparticles (NPs), lipid vesicles, carbon nanotubes, quantum dots, etc. in order to enhance the effectiveness and longevity of chemotherapy. Until recently, a variety of nanocarriers have been used as treatment solid tumours such as lung, brain, pancreatic, liver, and breast, in a number of trials. Nanocarriers, amongst the several extant nanosystems, have the potential to alter traditional medicine by minimising side effects and allowing for the controlled release of medicinal chemicals. In addition, their compact size makes intracellular absorption easier. Here, we take a deeper look at the therapeutic potential and way of action of nanomedicines in the fight against drug resistance. The importance of cancer cell-specific targeting is also debatable.

## Abbreviations

CMC	Critical micelle concentration
CNt	Carbon nanotubes
DDSs	Drug delivery systems
DOX	Doxorubicin
EBC	Enhanced blood clearance,
EMA	European medicines agency
IRP	Improved retention and permeability
LSST	Lower specific stimulation temperature
MWCNt	Multi-walled
NLCs	Nanostructured lipid carriers
NIR	Near-infrared
NPs	Nanoparticles
PDT	Photodynamic treatment
PEG	Polyethylene glycol
PNIPAM	Polymers include poly (N-isopropyl acrylamide)
pHLIP	PH (Low) insertion peptide
PNBs	Plasmonic nanobubbles
QDs	Quantum dots
SERS	Surface enhanced Raman scattering

SiQDs	Silicon quantum dots
SLNs	Solid lipid nanocarriers
SMANCS	Styrene maleic anhydride-neocarzinostatin
SWCNt	Single-walled

## 13.1 Introduction

In the globe, cancer ranks as the second most prevalent cause of death [1, 2]. The treatment of cancer with precision and free cancerous cells requires chemotherapy [3, 4]. Chemicals are used in chemotherapy to either kill or stop the development of cancer cells [5]. Chemotherapy, which involves using cytotoxic chemicals in their free form to destroy cancerous cells or prevent cancer cell proliferation, is still the go-to medication for solid tumours, especially when it comes to instances of cancer of the breast, hepatic, lung, pancreas, and brain. The reason why antineoplastic medications' therapies are insufficiently successful is because of their non-specific cytotoxicity, and rapid metabolism with poor pharmacokinetics [6–8]. The early diagnosis and treatment of malignancy, meanwhile, continue to be hampered by current technology. Cancer treatment remains far from ideal since it is afflicted by significant shortcomings, despite considerable advancements in traditional treatment choices like chemotherapy and radiation therapy. Current cancer treatments frequently struggle with imprecise systemic distribution of anticancer drugs, insufficient drug quantities accessing the tumour site, unacceptable cytotoxicity, the inability to assess therapeutic outcomes, and the emergence of multi-drug resistance [9–11]. To anticipate effective therapy and treatment outcomes, existing prognostic and diagnostic categories are inadequate [12]. Negative outcomes will keep happening in the type of individual overall survival that are poor and the development of multidrug resistance. Due to such risks, nanocarriers have already been tried as rather promising methods for cancer treatment. Anti-neoplastic may create chemically covalent connections on the exterior of the nanocarrier, become physically deposited there, or be retained inside the nanocarrier [13].

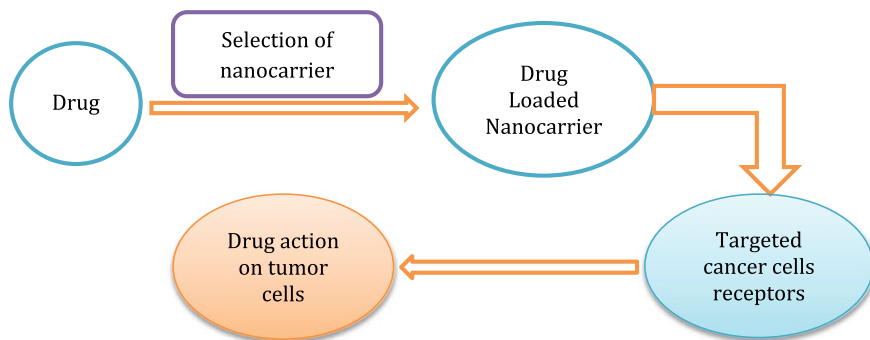
## 13.2 Cancer Nanotechnology: A New Paradigm in Cancer Treatment

As with any treatment of cancer, the main challenge is to deliver the correct medicinal agent concentration to tumour locations, eliminating malignant cells while causing the least amount of harm to healthy cells. With this perspective, it is essential to develop single drugs that have a great deal of potential to significantly impact

preventing cancer, diagnosis, and therapy. In order to address these issues with traditional chemotherapeutic medications, a number of ligand-targeted drug delivery techniques, radio-immunotherapeutics, such as immunotoxins, and pharmaceutical immune conjugates, are being researched. These new tools will be used in the treatment of cancer [14]. Restrictions in their distribution continue to be a significant issue, despite the fact that these concatenated medications have demonstrated effectiveness that is encouraging when compared to traditional chemotherapeutic treatments. Recent developments indicate that nanotechnology is going to have significant influence on illness prevention, diagnosis, and medication. Nanotechnology is the production and manipulation of substances at the nanometer dimensions to produce products that display unique qualities. Cancer nanotechnology is developing as a new area of multidisciplinary study that spans the fields of biology, engineering, chemistry, and medicine. It is anticipated that this research will result in significant advancements in the detection, identification, and cancer therapy [15]. A tempting solution for preferentially eliminating cancer cells while seriously harming healthy cells is the notion of developing more efficient cancer therapies by manipulating them at the nanoscale. One of the most promising areas for cancer treatments is nanotechnology, a multidisciplinary discipline [16]. By creating clever, biocompatible nanomaterials for drug administration, which is the most relevant use of nanomedicine, nanoparticles (the medical use of nanotechnology) has the amazing ability to revolutionize cancer therapies and diagnostics. Nanocarriers have recently been used in an unheard of way, notably in the 10–100 nm size range, as an advent of therapies for the treatment of cancer. The USFDA has authorised the use of liposomes and albumin nanoparticles as two therapeutic nanocarriers in clinical settings. Another instance of an improved retention and permeability (IRP)-based nanovector use for breast cancer treatment is liposomal doxorubicin, albumin-bound paclitaxel (Abraxane1) [17, 18]. These nanosystems have four distinctive qualities that set them against other anti-cancer therapy: (i) they can be constructed to carry a significant therapeutic “payload” and also have clinical or diagnostic characteristics taken by individual; (ii) they can be coupled to multivalent targeting moieties to generate higher specificity and affinity for target cells (Fig. 13.1), and (iii) they can facilitate various drug particles to allow combinational chemotherapy. The nanocarriers can concurrently boost against cancerous activity and decrease cytotoxic activity by employing both inactive and active aiming mechanisms to raise intracellular drug levels in cancer cells whilst limiting damage in normal cells [19].

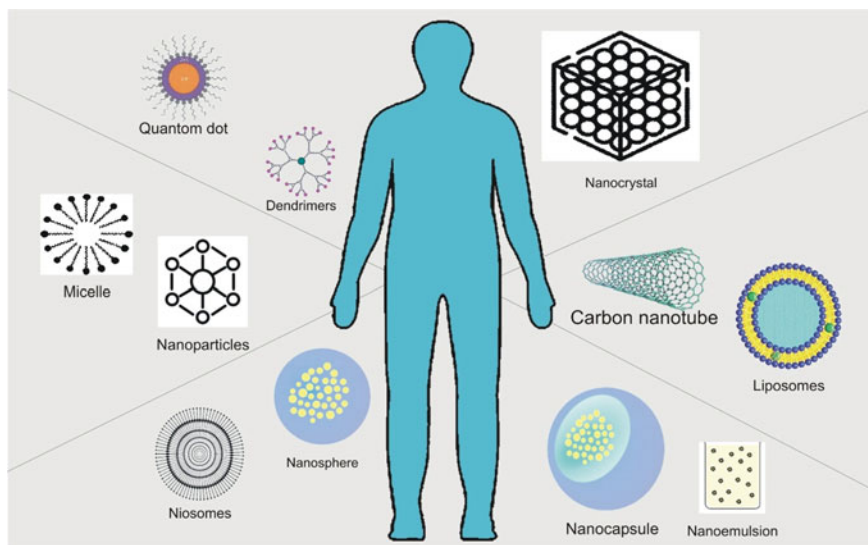
### 13.3 Nanotechnology Approaches for Cancer Treatment

This chapter describes the various topologies of nanosystems as well as the most current advancements in nanotechnology in the realm of treating solid tumours. By concentrating on this field’s efforts, we can create novel therapeutic approaches and enhance the treatment of solid cancers. Nanoparticles, nanocrystals, micelles, nanosphere, carbon nanotubes, niosomes, liposomes, dendrimers, quantum dots,



**Fig. 13.1** Schematic diagram for representation of affinity for target cells

nanocapsule, etc., are a few instances of the natural and artificial materials who have been employed to create nanocarriers based on nanotechnology [20, 21] (Fig. 13.2). They've shown some really big promise in the therapy of carcinoma by improving drug efficacy and minimising systemic adverse effects.



**Fig. 13.2** Illustration of the nanocarriers used in intelligent medication delivery systems

### 13.3.1 *Liposomal Nano-Carriers*

Amongst the nanocarriers used to treat cancer, lipid-based nanocarriers have made great progress. There are currently different types of lipid-based formulations, such as liposome systems, solid lipid nanocarriers (SLNs), and nanostructured lipid carriers (NLCs) (Fig. 13.2). These lipid-based systems tend to be less toxic than other DDSs, such as polymer NPs, because of their biocompatibility and biodegradability.

A lipid bilayer surrounds a central cavity that may be filled with chemotherapeutic medications for transport to tumour locations to form liposomes, which seem to be spherical drug carrier vehicles created intentionally [22, 23]. As a result of phospholipid's amphiphilic characters as well as the aqueous environment's thermodynamic characteristics, which force the self-assembly into a thermodynamically advantageous orientation with a hydrophobic section contained within the NP core, the formation of liposomes is very simple [24]. Liposomes have by far emerged as the most effective preparation for therapeutic use [25]. Natural phospholipids, cholesterol, and other lipids can form based on the structure of liposomes, which makes them perfect carriers for therapeutic compounds with differing solubilities because hydrophilic substances can be integrated inside the core (for example, Doxil<sup>®</sup>, entrapped doxorubicin (DOX) table 1) and hydrophobic medicines can be housed inside the lipid bilayer [26]. Lipid vesicles can thereby deliver either aqueous-soluble or poorly soluble medications to a specific place. In addition, they are drug-protective and have minimal immunogenicity and safety. Polyethylene glycol (PEG), a biocompatible and benign polymer, is added to the exterior of liposomes to generate a protective barrier that prolongs circulation by preventing the reticuloendothelial system from being cleared.

There are numerous ways to make liposomes, including solvent injection system [27], reverse phase evaporation, thin layer hydration methodology (also called as the Bangham approach), and detergent filtration [28]. Conventional techniques have several drawbacks. Some unique methods, such as supercritical fluid innovation, supercritical reverse phase evaporation, and the supercritical anti-solvent approach have been developed to overcome those restrictions.

### 13.3.2 *Micelles*

Amphiphilic compounds exhibit special self-assembly properties when contacted to a solvent because they include either both hydrophilic and hydrophobic regions. The polar sections of a co-polymer are drawn towards the solvent, whereas the hydrophobic components of the co-polymer orient far from the solvent if indeed the solvent is aqueous loving as well as its quantity surpasses the critical micelle concentration (CMC). Thus, the hydrophilic regions create a corona, and the hydrophobic parts create a centre. Figure 13.2 shows what is known as a straight or normal polymeric micelle [29, 30]. On the contrary side, amphiphilic substances subjected

to a hydrophobic solvent result in the formation of an opposite structure called a reverse micelle. In some kind of reverse micelle, the aqueous loving regions create the core while the aquaphobic sections create the corona. Notable instances of micelles include PG-PCL, PEG-PCL [31], PEEP-PCL [32], and PEG-DSPE [33]. The solubility of the copolymer being utilised determines how micelles are formed. There are two techniques employed for a co-polymer that is largely water soluble: immediate dissolving and film forming. If the co-polymer is not easily soluble in aqua, however, screening or oil in aqua technique is performed [34].

By bridging the CMC, micelles run the risk of premature release of drug. Additionally, contact to blood and unimer uptake to plasma protein can upset the balance here between micelle and blood. A clever micelle is the answer to this dilemma. Micelles are often cross-linked, which is the disulfide-based joining of two polymer chains, to solve the aforementioned issues [35]. The cross-linking systems come in two varieties: central cross-linked polymeric micelles as well as outer cross-linked polymer micelles. Folic acid, sugars, peptides, aptamers, antibodies, and other forms of ligands are employed to adorn the micelle surface so as to aggressively attack cancerous cells. It is feasible to improve the properties the micelle's corona or core in order to release the medication for cancer therapy at the proper quantity. Ultrasound, enzymes, temperature fluctuations, pH gradients, and oxidation are some of the triggers employed in micelle-based delivery system. For the synergistic benefits in the therapy of cancer, the co-delivery method that used a multipurpose micelle is crucial. A heat-sensitive micelle-based co-delivery device was developed by Seo et al. [36] that can transport genes and anti-cancer medications simultaneously. Using an imaging substance, you may adorn the micelle's exterior. Kennedy and colleagues reported on the use of ultrasonography to image tumours while simultaneously administering doxorubicin [37].

### 13.3.3 *Quantum Dots (QDs)*

Quantum dots are 2–10 nm in diameter and are inorganic luminous semiconductor nanoparticles made up of 10–50 atoms [21]. Their excellent control over size and shape enables precise manipulation of their emission and absorption characteristics. They are durable for months without deterioration or change and have been extensively explored for optical imaging applications in live systems [21]. For the purpose of marking tumour cells, specific ligands have been added to QDs to enable precise targeting [38]. They are therefore certain to be selected as long-term, highly sensitive, and multi-contrast diagnostic agents used for in vivo detection and diagnosis of cancer [39].

To get over the limitations of cell membranes, several scientists are now concentrating on employing quantum dots as carriers for the transport of genes. Bifunctional silicon quantum dots (SiQDs) were created by Klein and colleagues to be used as a self-tracking delivery method for ABCB1 siRNA [40]. According to Li et al.'s study on the glutathione-mediated liberation of active plasmid DNA with positive

energy CdTe quantum dots, such QDs may be used to selectively and visibly unload cargo in live cells [41]. It has also been looked into if quantum dots may be used to treat cancer via radio- and photo-sensitization processes. Quantum dots, which have electrical levels of energy in the 1–5 eV band, can serve as light sensitizers in photodynamic treatment (PDT), which was recently authorised as a therapeutic option for a particular kind of cancer. According to Juzenas [42], quantum dots have a significant atom and electron abundance that allows them to absorb highly energetic photons and operate as radiosensitizers to harm cancer cells in a limited and targeted manner.

QDs-based tumour detection and therapy may be applied to deeper tissues and provide an optical guidance for organ surgery when combined with near-infrared (NIR) optical imaging technologies. Nevertheless, since they are made up of dangerous heavy metals, QDs' cytotoxicity cannot be disregarded for their uses in vivo. Therefore, in order to assure their safety for future uses to humans, it is vital to rigorously evaluate their toxicity.

### ***13.3.4 Carbon Nanotubes (CNT)***

A subclass of carbon allotropes known as fullerene includes carbon nanotubes (CNT), which may take on a variety of shapes, including nanospheres, ellipsoids, tubes, and more. A graphene sheet is termed as a CNT when it is roll down into a flawless circular tube. Both single-walled (SWCNT) and multi-walled (MWCNT) CNT are available [43]. Additionally, nanoparticles between 50 and 100 nm are easily consumed due to the CNT's significant absorption spectra in the near-infrared range. This particle is an ideal match of photothermal ablation. While PEGylated SWCNT can localise in a particular cellular division, MWCNT can pass over the barriers of several cell organelles. Carbon black and graphite may be heated in a regulated combustion environment to create CNT. The synthetic CNT shape, size, quality, mechanical properties, and purity cannot be controlled by this procedure. Laser ablation, chemical vapour deposition, and electric arc discharges [44] have all been described as solutions to the regulated combustion environment's drawbacks. SWCNTs are more effective than MWCNT in delivering drugs due to their more delineated walls and the comparatively greater number of structural flaws in MWCNT [45].

To make CNT intelligent, they must either be physically or chemically specific job roles [46]. The process of PEGylation is crucial for increasing solubility, avoiding the reticuloendothelial system, and reducing toxicity. Thermal responsive polymers include poly (N-isopropyl acrylamide) (PNIPAM). CNT might be modified for temperature stimulation using PNIPAM because of their lower specific stimulation temperature (LSST). For medication release that is enzyme sensitive, a disulfide bridge centred on methacrylate cysteine is utilised. The best choice for pH reactive is a polymer (ionizable) with such a pKa value around 3–10. When the pH changes, weak bases, and acids exhibit a shift in the ionisation state [47]. Nanostructures CNT can cross the BBB, according to recent research. CNT has demonstrated



potential for transporting plasmid DNA, antisense oligonucleotides, siRNA, and aptamers. It can be utilised for photothermal therapy of a cancer location in conjunction to gene delivery. As diagnostic instruments for the early identification of cancer, nanostructures CNT can be applied [48–50].

### 13.3.5 Dendrimers

Dendrimers are synthetic large molecules having tree-like architectures with the elements organised in several limbs and sub-limbs emanate from a core structure [51, 52]. They are made in a series of processes from branching monomer units. As a result, it is feasible to manipulate their molecular characteristics, which rely on the branching monomer units and include size, dimension, shape, and polarity [51]. Due to their void interior holes and exterior moiety, these highly branched structures provide special interfacial and physiological performance benefits. They may thus be changed or coupled with a variety of intriguing molecules and have a huge potential for solubilizing hydrophobic medicines [52]. Dendrimers possess proven considerable possibility in the creation of anticancer medication delivery mechanisms based on their unique characteristics.

The well-defined multivalency of dendrimers is frequently used to covalently attach particular targeting components, such as folic acid, sugar, biotin [52], antibody, and epidermal growth factors, in order to achieve effective medication targeting to tumour tissues. Drugs used for treating illnesses can also be coupled with dendrimers or contained inside them. In order to create grouped molecules for focusing on cancerous cells that exasperate the very dependable folate receptor, Choi and colleagues developed generation 5 polyamidoamine (G5 PAMAM) dendrimers covalently linked to folic acid and fluorescein. These compounds were then connected with complimentary DNA oligonucleotides. The DNA-linked dendrimer complexes may connect to KB cells with specificity, according to in vitro tests, and they might be employed as diagnostic tools for cancer treatment [53].

### 13.3.6 Niosomes

Niosomes, non-lecithin transporters, resemble liposomes in form but are sturdier. These are nanocarrier systems created by nonionic surfactants, and they offer several benefits including biodegradability, biocompatibility, biodegradability, as well as the capability to encapsulate both lipid-soluble and aqueous-soluble medicines. They were created to get over liposome's restrictions, particularly those brought on by phospholipid oxidation. In addition, the bilayer fluidity and less viscosity of niosomes may be readily controlled, and they have a longer lifespan [54, 55]. Pereira et al. [56] effectively created pH (Low) insertion peptide (pHLIP)-coated niosomes. Niosomes

covered with pHLP are shorter and much more stable than pHLP-coated liposomes, with good tumour targeted and pH-dependent cellular uptake. As a result, lipophilic and/or hydrophilic medicines can be successfully delivered to niosomes, which can then enter cells in a pH-dependent way. Niosomes' adaptability improved the oral absorption of drugs. However, because the niosome has a limited capacity for encapsulation, multiple surfactant mixtures are required to encapsulate diverse hydrophobic compounds in its bilayer membrane and preserve the long-term stability of the nanovesicles.

### ***13.3.7 Nanoparticles***

The medicinal substance of interest is contained inside the polymer matrices of such submicron-sized colloidal particles, or it could adhere to the surface or be adsorbed. Through surface changes, nanoparticles are directed to certain places where they interact biochemically with specific receptors on target cells [56]. The capacity of nanoparticles to carry medications to the target region while navigating various biological obstacles, including the blood–brain barrier, is another significant function of nanoparticles. After such an intravenous injection, brain scapegoating is made possible by covering the medicine-loaded nanoparticles using polysorbates, which allow them to pass across the blood–brain barrier [57]. Acharya et al. [58] creation of immuno-nanoparticles with increased effectiveness against the MCF-7 breast cancerous cell line included fulfil the required nanoparticles linked to epithelial growth factor antibodies. By precisely directing the medicine to the core of breast tumour cells by combining a core localization motif to the surfaces of the nanoparticles, Misra et al. [56] have increased the medicaments effectiveness of the strong anticancer agent doxorubicin. In order to dissolve curcumin in water phase at clinically meaningful densities, safeguard it against hydrolytic breakdown and then in vivo biotransformation, and produce curcumin in a regulated fashion, Mohanty and Sahoo [19] developed a nanoparticulate delivery mechanism using pluronic F-127 and glycerol monooleate. It is widely acknowledged that the creation of cutting-edge methods for early detection of cancer and efficient treatment would significantly increase survival of patients. In order to fine-tune the emission and absorption characteristics of nanoparticles, novel artificial techniques have been devised [59]. The creation of multifunctional nanoparticles with the capability to deliver drug candidates and image specifically targeted tumours is made feasible by the development of nanoparticles as imaging techniques [60]. Commercially available nanoparticles shown in Table 13.1.

**Table 13.1** Typical pharmaceutical products based on nanocarriers available today [65]

Drug	Brand name	Nanocarriers	Indications
Styrene maleic anhydride-neocarzinostatin (SMANCS)	Stimalmer/Zinostatin	Conjugate of protein-polymer	Liver cellular cancer
PEG -L-asparaginase	Oncaspar	Conjugate of protein-polymer	Leukaemia acute lymphoblastic
Anti-CD20 attached to iodine-131	Bexxar	Radio-immunoconjugate	Low-grade, follicular, or transformed non-lymphoma Hodgkin's that is resistant or has relapsed
PEG: granulocyte colony-stimulating factor (G-CSF)	PEG filgrastim/Neulasta	Conjugate of protein-polymer	Preventing neutropenia brought on by chemotherapy
Anti-CD20 attached to indium-111 or yttrium-90	Zevalin	Radio-immunoconjugate	Low-grade, follicular, or transformed non-lymphoma Hodgkin's that is resistant or has relapsed
Daunorubicin	DaunoXome	Liposomes	Kaposi's sarcoma
Vincristine	Onco TCS	Liposomes	Non-lymphoma Hodgkin's with an aggressive relapse
Paclitaxel	Abraxane	Albumin-conjugated paclitaxel nanoparticles	Breast cancer with metastasis
Doxorubicin	Myocet	Liposomes	Combination treatment for Kaposi's sarcoma, ovarian cancer, and recurrent breast cancer

### 13.3.8 Nanocrystals

Nanocrystals are described as completely solid particles having a crystal-like quality [61]. Nanocrystal formulation has allowed for the recovery of several poorly soluble medications. Because of the fact that nanocrystals are constructed completely of the

drug or payload, they have special properties such as an enhanced ratio of surface to volume, stable rate of dissolution, augmented framework strength, and elevated medicine loading effectiveness. This eliminates the need for a carrier and leads to acceptable therapeutic levels at low doses [62]. Initially, nanocrystals were utilised enhancing oral bioavailability of poorly soluble medicines. Nanocrystal composition has attracted widespread interest for intravenous administration of anticancer medications, even if studies on the medication are still at the preclinical animal stage [61, 63]. Passively administering intravenous nanocrystals delivered to mononuclear phagocytic network rich in cell, tissues such as hepatic, spleen, and lungs due to macrophages' quick digestion [64]. The distribution of nanocrystals in vivo is significantly impacted by the surface, size, and shape functionalization of the particles. Nanocrystal properties such as size, solubility, stabilization, and bioavailability are frequently influenced by the pH of the dispersion media, crystallinity production, and contaminants [62].

### ***13.3.9 Nanoemulsions***

When two immiscible liquids are combined, a nanoemulsion is created where one phase is disseminated throughout the other. Typically, they are between 50 and 200 nm in size. Based on their technique of synthesis, nanoemulsions often comprise oil compounds or droplets scattered in an aqueous phase or watery droplets scattered in an oily phase [66]. As a result of their biodegradability, simplicity in manufacture, and regulated drug release, nanoemulsions have received extensive research as drug carriers for lipophilic chemotherapeutics [67, 68]. Additionally, nanoemulsions not only prevent medication deactivation in the gastrointestinal system but significantly improve the solubility of the pharmaceuticals, allowing for better drug absorption and dispersion. Due to the inclusion of additives that are widely regarded as safe, nanoemulsions also have strong biocompatibility. These additives have a high trapping effectiveness for hydrophobic components, physicochemical stability, and increased bioavailability, as well as higher effectiveness and safety.

### ***13.3.10 Nanocapsule***

Nanocapsules may be created using two methods: template-based and self-assembly. Because of their hollow spherical shape and capability to self-orientation into the vesicular framework in water solutions, lipid molecules and amphiphilic natured copolymers are excellent antecedents for the creation of stable nanocapsules compositions through a variety of processes. The template technique involves encasing a template component in a polymer shell, which can then be withdrawn to reveal an

unfilled polymeric shell. As an alternative, central particles can be created by traditional emulsion polymerization then removal of the core particles after the introduction of a separate monomer creates a cross-linked shell surrounding the central particle [69].

### ***13.3.11 Nanosphere***

In-depth studies have been conducted on nanospheres and nanorods, which are used in a variety of biomedical applications, including administering drugs, photo-irradiation-based treatment, bioimaging, diagnostics, and immunotherapy [70]. These entities are optically distinctive in that the nanospheres display a particular plasmon resonance and a high X-ray attenuation coefficient in proportion to their dimensions, while the nanorods show two distinct plasmon absorptions in line with respective aspect ratios [71]. Nanospheres, therefore, are interesting materials for bio-imaging and diagnostics, in addition to those coated with molecular structures such as surface-enhanced Raman scattering (SERS) sensors and photothermal compounds. Additionally, nanospheres may be used for photoacoustic treatment due to their optical feature of turning near-infrared light into thermal energy. Nanospheres have a high volume-to-surface ratio and thus are bio-inert, hence numerous experiments have been done to include medicines on their surfaces even though medications cannot be incorporated within inorganic materials. In order to identify and treat diseases in vivo, chemotherapies, genes, even photosensitizer medicines have been mounted on nanospheres [71]. Due to the fact that cancer cells have evolved sophisticated defence system against the body's own immune system, the research of nanocarrier applications in cancer treatment has recently extended to include succeeding immunotherapy. In order to modify the micro-environment and promote tumour growth, cancerous cells convey specific markers and take advantage of a number of immunological procedures, such as controlling the secretions and activities of T and macrophages cells, antigen presentation, and the creation of immunosuppressant mediators [72]. To lessen the potential adverse effects of advertising biodegradable polymeric nanoparticles, vaccines and antibodies have been used as carriers in antigen drug carriers; even so, the possibility of immune rejection of polymeric particulate has been noted, and the method of the immune function is not thoroughly grasped. For instance, despite the fact that polyethylene glycol (PEG) is frequently used during polymeric carriers to prevent protein adsorption and reduce non-specific cell adhesion, anti-PEG antibodies have been reported to be brought up on such administering of numerous PEGylated proteins and nanomaterials, that can reduce the treatment effectiveness of the administrated protein [73].

## 13.4 Cancer Diagnostics and Treatment Using Nanotechnology

Theranostics (diagnosis and treatment) is an innovative biological approach that combines diagnosis and treatment into one step. The main objective of accurate diagnosis is to specifically site particular (illness) cells or tissues in order to enhance the precision of the diagnosis and treatment. Theragnostic can assist us to combine important phases of a medical procedure, such detection, and treatment, and render a procedure quicker, more protective, and more effective. Nanoparticles have been used as the carriers of therapeutic and diagnostic substances in a number of theragnostic techniques. The creation of biocompatible nanocarrier as cancer diagnostic tools that would allow for unobtrusive detection and accurate cancer treatment is presently underway. These multimodal nanocarrier-mediated approaches show potential for enhancing cure for cancer percentages, decreasing adverse effects, and speeding up the course of treatment. In order to tailor the plasmonic nanobubbles characteristics in a single cell and assess their multifunctionality, Lukianova-Hleb et al. studies of the optical creation and monitoring of plasmonic nanobubbles (PNBs) surrounding gold nanoparticles in single live cells [74] is of particular interest. Magnetic nanoparticles can serve as both drug delivery carriers and detecting imaging techniques tools, according to many recent studies that have covered their engineering drawings, physicochemical characteristics, and therapeutic properties [75]. Shim et al.'s [76] integrated cancer treatment and diagnosis (theragnostics). In their work, the researchers explored the prospect of combining stimuli-responsive multidimensional optical imaging and stimuli-enhanced down regulation by coating tiny polyplexes conjugated to gold nanoparticles through acid-cleavable connections.

## 13.5 Aspects of Future Scientific Challenges

Every possibility has its share of difficulties. The same is true for nanocarrier. The body's sensitivity to nanocarriers, the system's cost efficiency, the variety and heterogeneity of cancer, as well as the absence of precise regulatory requirements are obstacles to efficient nano-drug delivery systems [77]. Nanocarriers transport and deliver the anticancer medications to specific areas to eliminate the cancerous cell. The outcome of the medicine-carrying nanocarriers is what worries people. Traditional nanocarriers can build up in several types of vital organs like the hepatic, spleen, lungs, kidneys, and cardiac, based on their chemical content, size, specific surface area, shape, surface charge, and existence or lack of a shell around them. Most nanocarriers do not leave the body after use; instead, they build up in the aforementioned essential organs. The toxicity that results from this deposition is a huge obstacle to the development of nanotechnology. There have been a lot of in vitro and in vivo research on toxicities in animal situations, but there has not been much on toxicity in humans. Toxicology research still has a very broad reach

[78]. Cancer is diverse and heterogeneous; hence, the different forms of cancer are yet unknown. Additionally, each person's experience with cancer may be physically different. Consequently, personalising medical care is a significant difficulty as well. Anti-cancer behavioural strategies on DNA/RNA offer a promising future for enhancing pharmaceutical safety and personalization. Consequently, the creation of nanocarriers as carriers of genetic material to eradicate cancerous cells may be a potential study area [79].

Traditional nanomaterials, like the reticuloendothelial system and enhanced blood clearance (EBC), confront several biological obstacles on the path to identifying cancer cells. Traditional nanocarriers are altered utilising a number of techniques, such as PEGylation and ligand patching, to overcome these obstacles. Additionally, the nanocarriers must be designed and synthesized in order to release the medications at specific areas when stimulated. The cost of the finished product increases as a result of these alterations, which result in more production stages. Any product that is released has to have a favourable cost–benefit ratio to be competitive [80].

The biggest obstacle to the commercialization of nanocarriers based dosage form is obtaining regulatory authority clearance. In the review and approval, the European Medicines Agency (EMA) and the FDA play important roles. The amount of FDA-approved nanocarrier-based anti-cancer treatments is quite small, even if there are numerous items in the queue, 23 years since the first nanocarrier-based anti-cancer medication, Doxil, was announced in 1995. Manufacturers must demonstrate the items' short- and long-term security for the human body in order to receive governmental clearance. Consequently, launching an item while doing all the required processes is highly time-consuming and labor-intensive. Sometimes even the clearance process is made more difficult by the lack of explicit rules. To overcome these obstacles, an agreement between scientists, industry, and regulatory agencies is required [81].

## 13.6 Conclusion

In order to decrease the danger of medication tolerance and specifically target various forms of cancer, the adaptability of NPs allows them to boost pharmacological synergies with better control of medication dispersion in time and space. Several active medicinal compounds have been coupled with a variety of biocompatible nanoscale substance carriers. Nevertheless, the increasing intricacy of the nanoformulation likely results in higher toxicity, more expensive manufacture, and problems in manufacturing procedures. To evaluate the interactions between nanomedicines and biological systems, more sophisticated technologies are required [82]. The primary drawbacks of various NPs distribution channels may be related to the loading percentage and encapsulation effectiveness of effective medicines, the two fundamental metrics utilised to assess nanocarriers. For example, liposomes have a quick release time and a small encapsulation rate. More critically, it can be difficult to rationally combine various medications with diverse mechanisms of action because most

DDS merely combine medications for co-delivery, independent of distributive pharmacokinetics in tumour locations. Additionally, proteins instantly coat the surface of the nanoparticles when they directly interact with live cells *in vivo*, impacting cellular uptake, inflammation, deposition, and nanoparticles breakdown [83]. The development of several nanocarriers lays the groundwork for its therapeutic use. Although nanocarriers offer many benefits, the FDA has only authorised a small number of them. Innovative nanocarriers' effective transition from pre-clinical to clinical testing requires the precise identifying of patients appropriate for clinical trial investigation, a complete knowledge of their modes of action, as well as the implementation of effective educational and collaborations between industries at various phases of growth. On an industrial and commercial level, there seem to be a number of evident difficulties, such as repeatability, non-uniform size, uneven framework, sterilisation, and preservation for mass manufacturing [84]. Long-term toxicological hazards arise from the buildup of nanodrugs in undesirable tissues and organs. Consequently, it is important to take into account how NPs are biologically distributed following systemic treatment in preclinical and clinical research.

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**Pankaj Sharma** have become attracted to Pharmacy as it combines Maths and Science together and shows how these subjects affect lives every day in a positive way. A Pharmacists role is very vital to ensure the right medicines are supplied in an effective way hence it will allow me to work with a range of patients to achieve a lifelong career as a Pharmacist. My pharmacist journey was started just after completing my graduation. My keen interest was explored towards the pharmaceuticals after qualifying GPAT and getting scholarship during my M.Pharm.

I have gained valuable knowledge studying Chemistry, Biology and Pharmaceutics which will be beneficial for the Pharmacy course. In Chemistry, I have done a series of experiments which require analytical and evaluative skills such as accurate reading when using burettes. I find the organic Chemistry module rather interesting as I enjoy studying the different reactions of aldehydes and ketones and how these reactions and organic products differ due to the different functional groups present in each compound. Another aspect of chemistry I enjoy is the purification of organic compounds. My Ph.D. guide encouraged me for do something for society so I decided that my Ph.D. research work will be beneficiary for society. With my mentor I worked on “Development of Transdermal patches for malaria treatment” during my Ph.D. This work was also sent for getting patent from SOS, Pharmaceutical Sciences, Jiwaji University, Gwalior M.P., India.

My week of work experience at the local Pharmacy was really inspiring; shadowing the Pharmacist and dealing with the different prescriptions given, was set to be really challenging and showed me how difficult the Pharmacists job can be, including giving advice to the patients and staff management. Other priorities at the Pharmacy included customer service and watching the Pharmacist carefully dispense medicines which I also saw as being valuable. I will be doing more work experience in the October holidays to really get an insight on the Pharmacists role in the Pharmacy.



**Dr. Vinay Jain** have always been astounded by the medicinal properties that plants possess. To use them in the welfare of mankind has always been there in my contemplation until my graduation (2002), which I completed from SOS, Pharmacy from Jiwaji University, Gwalior. This motivated me to select Pharmacognosy as one of my subjects in Major. I completed M. Pharm (2007) in Pharmacognosy from Barkatullah University Bhopal. Having completed my post-graduation, I started exploring phytochemicals in my professional journey as Assistant Professor in ShriRam College of Pharmacy, Banmore. Concurrently, I got a chance to be the part of training & placement team. This developed my soft skills to a large extent. I successfully defended my thesis entitled “Phytochemical and Pharmacological investigation of *Arisaema leschenaultii*” for Ph.D. I was awarded Ph.D. in Pharmaceutical science and technology from Berhampur University, Odisha. I was Co-convenor of Indo-Caribbean conference which was hosted by ShriRam College of Pharmacy in 2018. I was also the organising secretary of national conference on “The Future Prospect in Pharma-Marketing” hosted in association with IPGA. Till date, I have guided more than 20 undergraduate and post graduate students in major projects. My CV today hosts about 30 papers which have been published in distinguished journals/books of international and national repute which are indexed in SCI and SCOPUS. I have presented more than 20 papers in national and international seminars and conferences. I was also privileged to get grants from technical professional bodies like AICTE and MPCST for organising conferences. I am life time member of Indian Society of Pharmacognosy. I always try to keep my staff highly motivated with my open-door policy for grievance redressal and with efficient leadership skills because I believe that only a highly motivated team creates a highly efficient institution.



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Prof. Tailang has been awarded Prof. M.L. Khorana Award by Indian Pharmaceutical Association in the year 2002 and ILLUSTRIOUS ALUMINUS AWARD—2016 by Dr. H. S. Gour University, Sagar (M.P.) He has been awarded SRF from Council of Scientific & Industrial Research New Delhi in 1993.

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