



RECENT ADVANCES IN DRUG DELIVERY SYSTEMS: A COMPREHENSIVE REVIEW

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Abstract:

Imagine the body's drug delivery systems as super-smart, miniature automobiles specifically designed to absorb drugs exactly where the system needs most. There has been phenomenal growth recently and much excitement about what's in the pipeline. Cases are legion in terms of drug delivery involving nanoparticles - think of an incredibly astute tablet that knows exactly when to deliver its benefits! These tiny men deliver just the right dose at exactly the right place, enhancing efficacy and minimizing side effects of medications. And there's the genius concept of tailored drug delivery modes: these devices can locate a particular location like a heat-seeking missile. Really quite fabulous! And check this out: resources adapt to your needs, like a sponge. This sucks only water in summer. It's all because of microencapsulation, which can be thought of as putting your drug inside safe until the day when the body is ready to open it, to let the medication inside. Mini-superheroes can look in more than one way: polymeric nanoparticles, metal particles, and liposomes, for example. They're all like little special agents, doing their one specific task. Protecting your brain from viruses or getting rid of cancer cells. The fact that these developments may eventually make these things simple in treatments is really amazing.

Keywords: Nanoparticles, target drug delivery, microencapsulation, bio-responsive materials.

Introduction:

The medication delivery networks are very much similar to the unsung heroes of the medical community. Such networks are crucial as they enhance the effectiveness of the medications and prevent side effects in the patients. Yeah, there are so many inconveniences when one is on medication or when one change to an injection.[1] Some drugs are too strong in one part of your body and too weak in another, or they might not dissolve well or get to the right location in your body. That's why these systems are important: They are simply brilliant ways of delivering the right amount of drug to the right part of the body at the right time. Today, we administer medications to patients in a myriad of ways: intravenous, oral, or up the nose. Intravenous, oral, or nasal medication delivery networks are like the unseen heroes of medicine[2]. That's incredibly important because medications work better, side effects are minimized among patients. A whole lot of hassle is involved with taking medication or getting a shot. For example, some medications may be too strong in one part of your body but not strong enough in another or just won't dissolve or get where they are supposed to in your body. This is why these systems are so crucial[3]. Basically, they are brilliant ways of getting right amount of drug to right site at right time. So, we want the drug not to degrade too fast outside of a body and that it retains all its properties-the proper acidity, for instance. It is just about finding that sweet spot where the medicine does the most good without any extra drama. Essentially, drug delivery system refers to piece of technology that helps

drugs reach their peak performance once they are introduced into the human body[4]. It is as if one gives them a VIP pass for them to enter directly into the cells, tissues, and the organs where they need to go so that the good stuff inside the medicine can be done properly. Now, to ensure those systems work like a charm, they have to work well with our bodies. This is the number one rule when concocting new medicine mixtures: we've got to make sure these little guys don't hit any roadblocks on their journey through our insides, not because of how the medicine was made, but due to our own biological bouncers. If we can do our homework on the barriers ahead of time, we can whip up a medicine that's a real superstar, giving us the most bang for our buck when it comes to how well it gets absorbed and does its thing. [5].

Nano-particle based drug delivery system-

Nanomedicine and the system of nano delivery came out as a super-exciting field that was really growing fast. The whole thing is about using the smallest stuff, like nanoparticles, to help us in diagnosis and treatment much better [6]. It's this review, almost like a tour, of the latest and greatest in this field, where scientists have developed how to use these little things to send medicine exactly to that place in our body [7]. It's sort of like having a few little robots that really know just how to get the right dose of medication to just the right place, without causing hassles elsewhere in your body [8]. We're going to talk about exactly just how these nanostructures do this as, basically, the ultimate delivery guys in our blood-hustling nonstop to get good stuff into the right places while avoiding the unwanted side effects. [9]

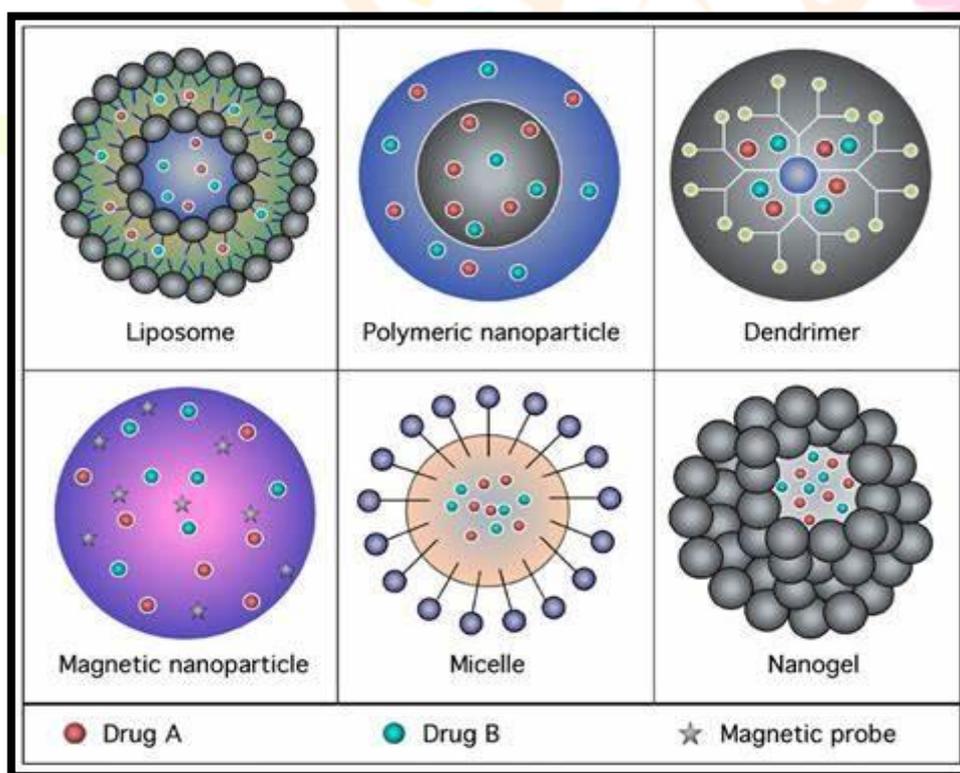


fig. no. 1- nanoparticle

Recent advancements in nano-particles drug delivery system:

1. Tailored Nanocarriers: Liposomes, micelles, polymeric nanoparticles are some of the clever little carriers that scientists use to deliver drugs. These tiny helpers are amazing because they can avoid affecting the rest of your body and instead take the medicine exactly where it needs to go. [10].

2. Smart Drug Delivery System: Smart drug delivery system is a giant leap in dealing with the burden of disease. It basically brings together nanotechnology, bioelectronics, and microfluidics within the smallest intelligent devices that will ensure only the right amount of medicine reaches in your body to the right location to treat your illness with minimal side effects. But then, with the help of sensors and all this stuff that goes down into the internet, systems can

monitor in real-time what happens. It sorts of acts like your personal health assistant that can fine-tune your treatment plan accordingly and the best is yet to come: it actually makes it easier and more convenient for you to take your medicine-this is the fast chance for staying on your treatment. [11]

3.Targeted Drug Delivery System and Active Targeting: Indeed, these are very smart drug delivery systems; targeting the medicine directly into the cells or to the most needy tissues. For example, such a system is an active targeting, akin to putting a GPS on the medicines: it makes them stick to the exact spots in the cells. In this way, there is a less possibility of unwanted side effects elsewhere in the body since it really hits much more of the bull's eye. [12]

4.Future Directions: Indeed, the new hype of tailoring nanomedicine for every individual, integrating diagnostics and treatments for ultra-targeted care, is small molecules that really take the management of drug things, and when you have taken small molecules, you will come to know that they have a very big handle in health. They really shake the thing and come out to be the thing that blows the next big how we take meds into our bodies, how they will give us some pain-free-long-lasting therapy-not only easy but super-effective too. [13]

Nanocarriers: Exactness Delivery for Bioactive Compounds

Nanocarriers, which are carefully designed to be really tiny with just the right mix of physical and biological properties, have a big edge over larger molecules. They're like the Swiss Army knives of the cell world, easily getting inside where they need to go. By using this cool tech called nanotechnology, we've opened up a whole new playground for giving you medicine. Now we can deliver those helpful little drug guys right to where they're needed most, making sure you get the best bang for your buck in treatment. [14]

Nanocarriers: These are minuscule carrier systems carrying and binding on to medicine; they get into that range they need to with much more efficiency when in use. They generally lie within a size between 1 and 1000 nano meters, which is indeed minuscule. What they do is transport the drugs and dispense them very finely so that the medicine goes directly where it is needed. That means treatments are more effective and some adverse effects are minimized that may appear from time to time. [15]

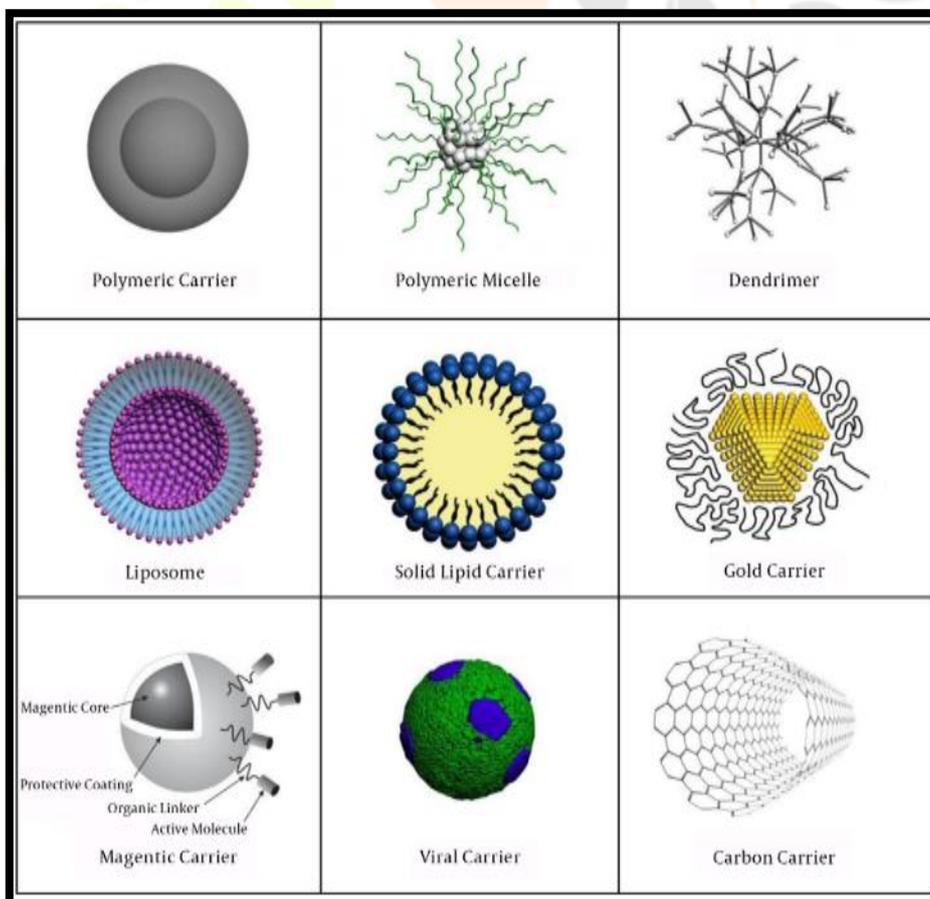


fig. no. 2-nanocarriers

Nanospheres and nano-capsules: Nanospheres and nano-capsules are like small intelligent vehicles; super-intelligent in delivery of the medicine, basically two small guys, who just happen to have a few pretty cool tricks up their sleeves that could guarantee our treatments were better, reached the right spot, and that the drugs were released at just the right time [16]. With these nano-capsules, well, it is like a little ball, hard outer body, like a gummy with something inside, but the outer part is made of material that guarantees the drug inside safe and sound, whereas the drug itself remains locked up inside. It is almost as if you have a treasure that cannot be opened except with a wish, and the treasure might as well be medicine to be administered at a destination [17]. The thing to be liked about this outer shell is that it could be engineered such that it lets the drug out at the proper time exactly, like a secret door opened at the right moment. Others are small balls, nanospheres, but designed to assist those medicines that don't mix well with water. That's pretty much like trying to dissolve a piece of chalk in your water bottle. Burying inside, these drugs become the best friend to water, easy for the body to absorb [18]. This is important for drugs that traditionally are not easy for our bodies to admit, or may not, on occasion, act more quickly or potently than we might desire. In short, these teeny-tiny carriers are perhaps the unsung heroes of the medicine world-they just may work quietly out of sight in order to help our medicines work as well as possible. [19]

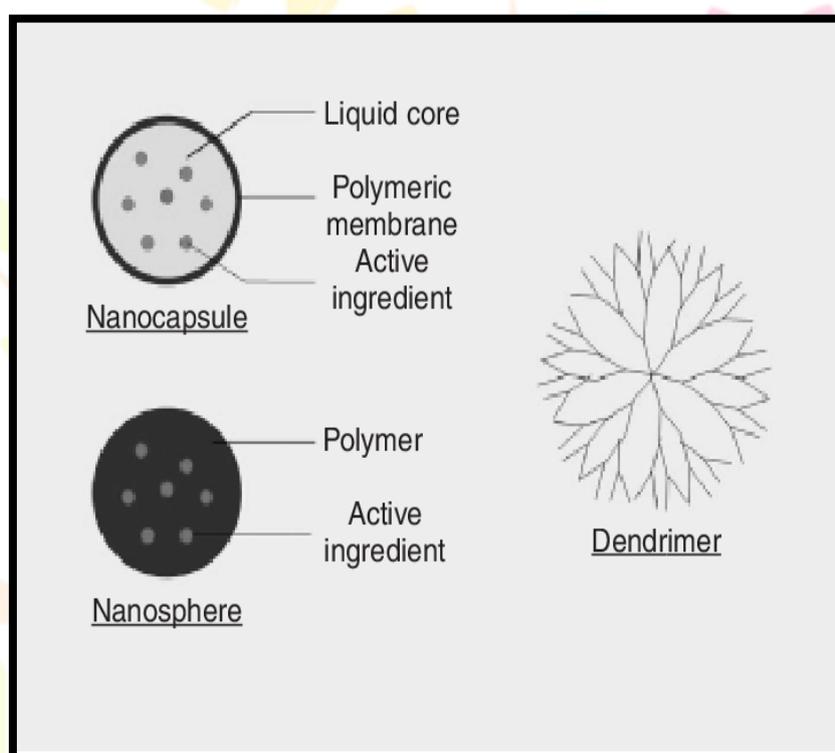


fig no. 3- nanospheres

Smart Nanoparticle: These nanoparticles are small and smart in that they can be "tuned" to "listen" for changes around them or certain signals. That is to say, scientists will potentially have control over when and where they release medicine. These signals can be thought of as something akin to changes in acidity or temperature, light shone upon them, or approaching some special tiny molecule in our bodies[20]. In such a manner, nanoparticles can be designed to directly deliver drugs into the target area, such as a tumour, thereby avoiding good and healthy parts of us. For example, certain nanocrystals are only super sensitive under more acidic conditions, say a tumour; they only release the drug they are carrying there. Thus, by targeting delivery, the rest of our body is exposed to less of the drug in question, thus to less of those pesky side effects and a safer treatment for patients. [21]

Smart drug delivery system:

Well, there has indeed been a sea change to the health and drug design arena today, and we're looking out for bright smart ways of making people feel better in the shortest possible time without much hassle [22]. Now it is this and this smart drug delivery system. These are essentially those small magic boxes that will make at the right time, the right

medicine reaches the right places in your body. Unlike these old medicines, most of which end in the wrong place, even worsen things, the new systems are rather like GPS or technology that can be set to react. For example, if a drug is overly acidic, it might create some sort of alarm system whenever it gets too hot or too cold, when light hits them[23]. This means that the medicine is targeted and does not go every which way; it goes only to where it is unwell. It's perilous because it makes the drugs work better and ensures the patient feels the effects with fewer side effects. The three types of triggers for these systems are: physical, chemical, and biological ones that come from within the body. It's as if there is a little doctor inside that makes the medicine work the way it's supposed to.[24]

1. Physical Stimuli-Responsive Systems:

These are highly intelligent delivery systems that can leverage those slight fluctuations in our body temperature to know exactly when to dispense their payload of drug. The researchers find these materials known as thermos responsive polymers, one of which is called poly(N-isopropylacrylamide), or PNIPAAm Poly(N-isopropylacrylamide) for short and were chomping at the bit to test them. Of interest are those experiencing a sort of phase change at certain temperatures that results in the 'release' of a drug just in time. [25]

Light-Activated Systems: Imagine a new cool way in which medicines are delivered inside your body almost like you had a small light switch inside. Well, that's what we call: light-activated drug delivery. Here it's just another method through which we use materials that are sensitive to light like tiny gold bits or special plastics to hang onto drugs[26]. Shine a light of a certain colour on those materials, voila, they change their shape, so they drop the drugs at just the right moment and in just the right place. It's like you have this smart little package that knows just when to give you the treatment you need. [27]

Ultrasound-Triggered Systems: You see, ultrasound is one of these rather cool devices that allow doctors to actually look inside your body without opening up a little window. And then it does something quite marvellous it gets tiny delivery systems-including liposomes and polymeric micelles-to release medical cargo just at the right time and in the right place. As if the ultrasound waves are tickling them, and they're going, "Oh, behold, look, here comes the drug that needs to get out.". And so, the dope will slowly leak out, like just the right amount of jolt to pop a soda bottle. [28]

2. Chemical Stimuli-Responsive Systems:

pH-Sensitive Systems: Well, so these pH-sensitive drug delivery systems are actually very smart, right? They are exploiting the fact that not all areas of your body have the same acid-base chemistry. The tumour, inflammation sites, gut is more basic. It's exploiting the quirk that some parts are more acidic or more basic than other parts which are in good order. Like, you know when you have a cold, and you find the taste of food weird.[29]

Redox-Sensitive Systems: Redox-sensitive systems take advantage of the disparity in oxidative reduction levels between normal and cancerous tissues; it normally happens that there is an oversupply of a scavenger molecule called glutathione in cancerous cells. Therefore, these molecules break some particular bonds while coming in contact with certain polymers that are sensitive to such conditions and release drugs being held by them. [30]

3. Biological Stimuli-Responsive Systems:

Enzyme-Sensitive Systems Some drugs are designed to be the "special keys" that "open locks" only in sick tissues. For example, in cancer certain excess enzymes are produced. These can break up special polymers to which drugs become attached[31]. A beautiful system assures the drugs are released precisely where they are needed-inside the tumour itself. So it doesn't roam all around the body side by side with those side effects here and there. More so, it's giving the drugs VIP cards to party with the disease instead of letting them crash the wrong one. [32]

Targeted Drug Delivery and Active Targeting:

Ligand-mediated targeting: Targeted drug delivery systems have come to be called the GPS of the medical world. Now, that is changing ways diseases are treated today. Gone are the days where there is this gobble of pills inside your body and hoping it reaches where it needs to. They smugly have the drugs go to specific problem areas[33]. This is huge, because the old route means the good stuff never reaches its destination and therefore isn't very effective in

creating side effects no one wants. In TDDS, the "intelligent mailman" is delivering the medicine right to your doorstep of sick cells while healthy ones are waving hello in their safe neighbourhood[34]. Much more effective than that lousy mailman who lets the letters get all soggy and the newspaper soaked. Precision medicine does that: hit bull's-eye. These systems use some pretty crafty tricks to get the job done. There's passive targeting, which is almost like letting the drug flow with the body's natural currents to the sick areas. Active targeting involves essentially giving the drug a homing device, where drugs while in transit seek out bad cells[35]. And then of course there's physical targeting, which is much more hands-on, such as using little tools to get drugs, precisely in the right place. So TDDS could be considered as having a "doctor inside" you, navigating your highways and confirming that the medicine does its thing without making a ruckus elsewhere. Almost like having a VIP pass to the healing party, and only sick cells on the guest list[36].

1. Passive Targeting:

Enhanced Permeability and Retention (EPR) Effect: This EPR effect is the most broadly used method in the passive targeting and is under specific application to cancer therapy. What makes tumours special is their disorganized network of blood vessels, which could be, for some point of view, compared to a leaky system of pipes. Such a system makes the process in which are quite tiny things-for example, nanoparticles or drug transporters-tend to accumulate more easily in such areas than healthy tissue in the entire body. That is sort of like a leaky pipe, which would collect much water compared to a good pipe.[37]

2. Active Targeting:

Ligand-Receptor Interactions: Active targeting provides a GPS on the carrier drug that we use in medicine. Essentially, it coats special molecules, such as antibodies, peptides, or aptamers, to coat the surface of the latter. It's like their keys for specific locks on the cell surface; it will improve in on it if there are too many receptors of that particular type, such as when it's a cancer cell.[38] For example, in the case of breast cancer, attacking the HER2 system, there is something akin to a sort of version of trastuzumab, which is a monoclonal antibody. More or less like a homing beacon, it latches onto the receptor in the cancer cells, taking drugs right to where they need to go. A little more promising finish for this Trojan horse dispatched to the enemy camp! [39]

Folate Receptor Targeting: Folate receptor is much more expressed in cancerous cells than in normal cells. Therefore, the clever trick was designed by researchers and put folic acid on the outer surface of medicine-carrying materials. In this way, it tries to reach only cancerous cells and avoid hitting the normal cells. This change enhances the treatment's efficiency, reducing side effects for the patient.[40]

3. Physical Targeting:

Magnetic Targeting: Magnetic drug targeting actually involves a very smart approach wherein these tiny drug molecules are tagged with magnetic particles. We can then send that point externally, magnetically-for example, to the centre of a solid tumour or to an exact point where there is infection. It's like giving drugs a GPS system so that you can have a capacity to control exactly where and how much of the treatment goes in without having to open someone up.[41]

Ultrasound and Light-Activated Systems: Then, by targeting, it could physically deliver medicine inside the body, right where they are needed inside the body via ultrasounds or even through light. For example, basically, ultrasound can be a magic wand for drugs, as it lets them go into tissue that we actually try to reach.[42] It can be likened to the song played with sound waves and the medicine that goes down. So, with the light-triggered system it's actually possible to simply shine a particular kind of light in this location to make this drug do its work simply on the surface of tissue; it's really pretty smart. [43]

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