

Cancer as a Global Health Threat: A Review of Pathogenesis, Prevention, Access to Care and Application of Nanoparticles in Cancer Treatment

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Abstract: One of the main causes of death in the globe is still cancer. Cancer is a disease where abnormal cells grow uncontrollably and can spread, often forming tumors in the body. These tumors can be either cancerous or non-cancerous (benign). Cancerous tumors can invade nearby tissues and spread to distant areas of the body, forming secondary tumors. Traditional cancer therapies, such as chemotherapy and radiotherapy, are associated with significant limitations, including lack of specificity, cytotoxicity, and multidrug resistance, leading to adverse effects and recurrence. Nanotechnology provides particular advantages for cancer treatment. By reducing its adverse effects, it has the potential to reduce systemic toxicity by directing drugs to target cancer cells specifically and creating functionalized particles for targeted treatment. Nanotechnology has emerged as a revolutionary solution in cancer diagnosis and treatment, offering advantages such as biocompatibility, reduced toxicity, and precise targeting of the tumor microenvironment. Nanoparticles, including liposomes, polymers, metallic nanocarriers, and quantum dots, provide improved pharmacokinetics, enhanced drug delivery, and customizable properties for greater therapeutic efficacy. This review explores the pathological and physiological impact of cancer, its types, and complications, with an emphasis on the transformative role of nanoparticles in advancing cancer treatment. This review focused on one of the modern methods used to treat cancer using nanoparticles.

Key points: nanotechnology; nanoparticles; cancer treatments; drug delivery.

1. Introduction

Cancer is a broad term for a group of diseases that can affect any part of the body. It is one of the leading causes of death globally, responsible for around 10 million deaths in 2020, which equates to about one in every six deaths. The most common types of cancer include breast, lung, colorectal, and prostate cancer. About one-third of cancer deaths are linked to risk factors like tobacco use, high BMI, alcohol, poor diet, and physical inactivity. Infections like HPV and hepatitis cause around 30% of cases in low- and middle-income countries (WHO,2022).

Cancer is a challenging and often incurable disease, with treatments historically known for being harsh. Even survivors face frequent tests and the fear of recurrence, often requiring more difficult and less effective treatments (Anisman & Kusnecov, 2022).

Some people develop cancer due to uncontrollable factors like inherited gene mutations, exposure to environmental toxins, or disasters such as the Chernobyl and Fukushima nuclear incidents. While some cancer cases, like those involving inherited factors, are unavoidable, individuals can reduce their risk through preventive measures. These include not smoking, limiting sun exposure, avoiding harmful foods, maintaining a healthy weight, exercising, avoiding alcohol, and getting vaccinated against cancer-causing viruses (Anisman & Kusnecov, 2022).

Cancer is the leading killer that threatens human life and health. In some low-resource countries and areas, cancer prevention and awareness campaigns are rare, and in crisis regions, these inequalities are exacerbated. Access to appropriate healthcare can become extremely difficult, leading to delays in accessing high-quality cancer services and treatments (UICC, 2023).

The introduction of nanotechnology has transformed cancer diagnosis and treatment, overcoming the limitations of traditional therapies like chemotherapy, radiotherapy, and immunotherapy, which often suffer from issues such as lack of specificity, cytotoxicity, and multidrug resistance. Although cytotoxicity and cytostasis can be achieved by radiation and chemotherapy, these treatments are frequently associated with serious side effects and an increased likelihood of recurrence. The unique benefits of nanoparticles (1–100 nm) include biocompatibility, decreased toxicity, superior stability, improved permeability and retention effect, improved pharmacokinetics of biologics and small molecules that otherwise have short half-lives in vivo, and precise targeting. These benefits make nanoparticles an effective therapy for cancer (Ovčevska & Muyldermans, 2020) (Sell, 2023). Liposomes, polymers, designed multifunctional antibodies, and nanoparticles made of metals (such as gold or silver), quantum dots, other biological molecules, or mixtures of these materials are examples of biocompatible nanocarriers. Nanomaterials can be engineered with specific properties to enhance drug delivery to tumors, improving efficacy and reducing toxicity. Key design features include surface-to-volume ratio, size, shape, surface charge, geometry, and stimuli-responsive properties. (Park et al., 2018).

This review aims to examine and understand the pathological and physiological effects caused by cancer, in addition to identifying the disease, its types, and its complications. Focus on the potential of different nanoparticles in cancer treatment.

2.1 Cancer

Disease represents an emergency situation that threatens the integrity of the human entity physically, socially, psychologically, and economically, hindering the patient's ability to perform their social roles and integrate into normal life. It poses a real threat to their psychosocial adjustment and is considered one of the most difficult experiences, especially when it involves chronic diseases, as identified by the World Health Organization, including cancer, kidney failure, diabetes, heart disease, respiratory diseases, and mental disorders. The occurrence of these diseases threatens the patient in all aspects of their life, potentially creating a real crisis that requires support to overcome and mitigate its negative effects (Ali, 2020).

2.2 A Historical Overview of Cancer

Humans and other animals have suffered from cancer throughout history. Evidence of cancer dates back to ancient times, with signs of bone tumors found in fossils, mummies, and ancient manuscripts. The oldest known description, from around 3000 B.C. in the Edwin Smith Papyrus, details breast tumors treated by cauterization but notes, "There is no cure." (ACS, 2018).

The term "cancer" originates from the Greek physician Hippocrates (460-370 B.C.), known as the "Father of Medicine," who used the words "carcinosis" and "carcinoma" to describe tumors. The Roman physician Celsus (25 B.C. - 50 A.D.) later translated the Greek term to "cancer," the Latin word for "crab." (ACS, 2018).

During the Renaissance, scientists like Galileo and Newton advanced the scientific method, which was later applied to studying diseases. Harvey's 1628 autopsies revealed blood circulation, while

Giovanni Morgagni in 1761 linked patient diseases to postmortem findings, laying the groundwork for oncology (ACS, 2018).

2.3 Definition of Cancer

Cancer is a disease where cells in the body grow uncontrollably and spread to other areas. Normally, cells divide to form new ones, replacing aged or damaged cells. However, this process can go wrong, causing abnormal cells to grow and multiply inappropriately. Figure 1 (SEER, 2021).

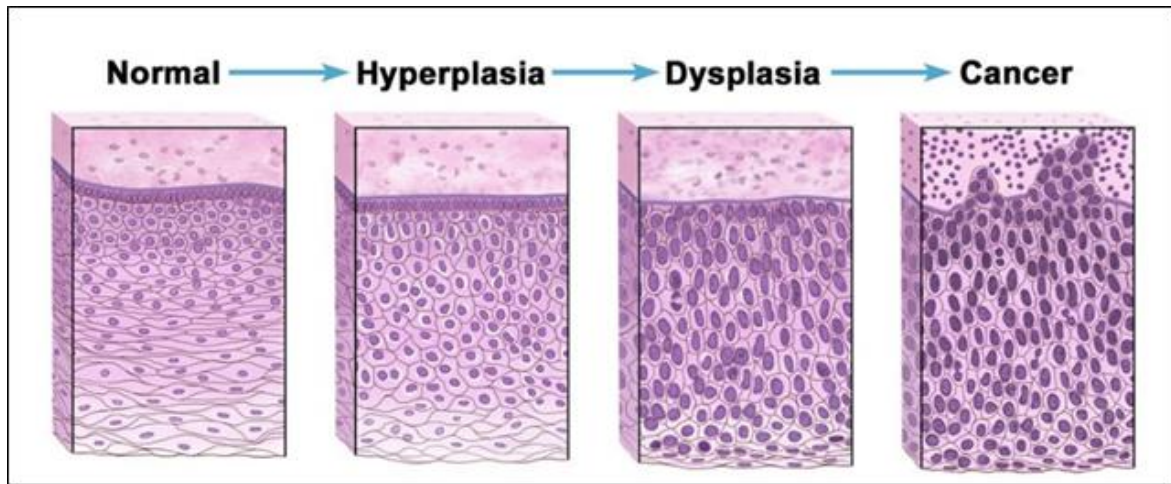


Figure 1: Normal cells undergo several changes to transform into cancerous cells (Terese Winslow LLC, 2014).

These cells have the potential to develop into tumors, which are masses of tissue. Tumors can be either cancerous or non-cancerous (benign). Cancerous tumors can spread to nearby tissues, invade them, and move to other parts of the body to create new tumors, a process known as metastasis. In addition, the metastatic cancer retains the same name as the original cancer it formed from. For example, when breast cancer spreads to the lungs, it is still called breast cancer and not lung cancer. Cancerous tumors, or malignant tumors, can spread to nearby tissues, whereas benign tumors do not. While benign tumors may grow large and cause serious symptoms, they typically don't grow back after removal, unlike cancerous tumors. Some benign tumors, like those in the brain, can still be life-threatening (SEER,2021).

2-4 Cancer incidence and mortality rates:

Cancer is a leading cause of death globally, responsible for about 10 million deaths in 2020 (Ferlay *et al.*, 2020). The most common causes of cancer-related deaths in 2020 were (WHO, 2022):

- A- Breast cancer (685,000 deaths).
- B- Colorectal cancer (916,000 deaths).
- C- Liver cancer (830,000 deaths).
- B- Stomach cancer (769,000 deaths).
- C- Lung cancer (1.80 million deaths).

Regarding injuries, approximately 400,000 children are diagnosed with cancer each year. The most common cancers vary between countries. Statistics have shown that cervical cancer is the most common in 23 countries. And the most common cases in 2020 (in terms of new cancer cases) were (WHO, 2022):

- A- Skin cancer (non-melanoma) (1.20 million cases).
- B- Lung cancer (2.21 million cases).
- B- Stomach cancer (1.09 million cases).
- B- Prostate cancer (1.41 million cases).

C- Colorectal cancer (1.93 million cases).

H- Breast cancer (2.26 million cases).

2-5 Stages of Cancer Tumor Development:

Cancers are characterized by uncontrolled cell growth, which intensifies during tumor development, allowing the cancer to destroy surrounding tissues and spread to other areas. Cancer cells are those that can break away from the primary tumor, migrate through blood vessels or the lymphatic system, and form new tumors at distant sites (metastasis or secondary tumors). For instance, a biopsy of a lung tumor may reveal that the cells originated from another organ, like the pancreas, indicating that the tumor is secondary and has metastasized from the pancreas. These metastatic cells have a distinct genetic signature that differentiates them from the more stable, non-migratory cells within the primary tumor. Cancer cells largely exhibit a programmed or mutated behavior characterized by rapid mitotic division, which becomes a biological threat when not restrained. (Anisman and Kusnecov, 2022).

Hanrahan and Weinberg (2011) identified six common characteristics among many forms of cancer. These distinctive features of cancer are illustrated in the figure. (2-3).

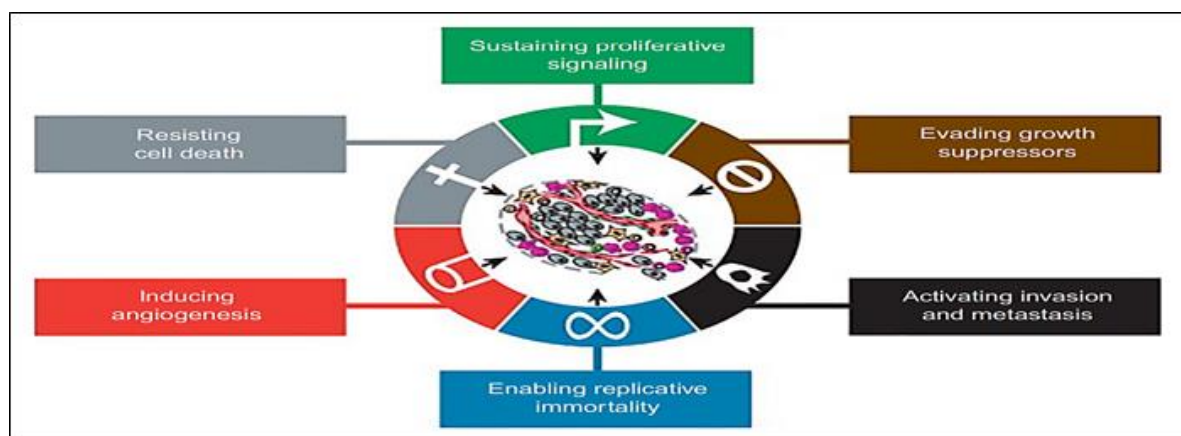


Figure (2-3) shows six characteristics of cancer that facilitate its growth and survival (Hanahan and Weinberg, 2011).

Cancer cells are self-sufficient in responding to growth signals and resisting growth-inhibiting signals. They evade programmed cell death, proliferate rapidly, promote their own growth, stimulate blood flow, avoid immune destruction, and spread through tissues. Inflammatory processes and gene expression changes also contribute to cancer growth (Anisman and Kusnecov, 2022).

2-6 Cancer Classification:

Cancer can be classified in two ways: by the tissue type or primary site where it originates, and by its location in the body. Histologically, cancers are grouped into six main categories.

2-6-1 Carcinoma:

Carcinoma is a malignant tumor originating from epithelial tissue, which lines or covers the body's organs and passages. It makes up about 80-90% of all cancers. These tumors are classified into two main subtypes:

A- Adenocarcinoma, which develops in a specific organ or gland.

B- Squamous cell carcinoma, which arises in the squamous epithelium.

Adenocarcinomas generally occur in mucous membranes and are first seen as a dense white mucous membrane resembling plaques, and they often spread easily through soft tissues. Squamous cell carcinomas occur in many areas of the body, and most carcinomas affect organs or glands that have the ability to secrete, such as the breasts that produce milk, or the lungs that secrete mucus, or the colon, prostate, or bladder. (NIH, 2023).

2-6-2 Sarcoma Cancer:

Sarcoma refers to cancer that originates in supportive and connective tissues such as bones, tendons, cartilage, muscles, and fat. The most common sarcomas generally occur in young people, often developing as a painful mass on the bones, and usually, sarcoma tumors resemble the tissues in which they grow. (NIH, 2023).

2-6-3 Myeloma:

Myeloma is a cancer that begins in the plasma cells of the bone marrow. Plasma cells are responsible for producing certain proteins found in the blood (NIH, 2023). When plasma cells become cancerous and proliferate uncontrollably, it is called multiple myeloma. In this condition, the plasma cells produce an abnormal protein (antibody), referred to by several names, including monoclonal immunoglobulin, monoclonal protein (M-protein), or M-spike (ACS, 2018).

2-6-4 Leukemia:

Liquid or blood cancers, such as leukemia, affect the bone marrow, where blood cells are produced. Leukemia involves the excessive production of immature white blood cells, which are ineffective and increase infection risk. It can also impact red blood cells, leading to anemia, poor clotting, and fatigue (NIH, 2023).

2-6-5 Lymphoma:

Lymphoma is a cancer that affects white blood cells, called lymphocytes, and can include both B cells and T cells (natural killer cells). It can be divided into two main types:

A- Low-grade or slow-growing lymphoma, where cancer cells grow and spread slowly.

B- High-grade or aggressive lymphoma, where the cells grow and spread rapidly.

This type of lymphoma is generally considered incurable. However, it mainly affects patients over the age of 60. This means that a person can die from other factors and not directly from cancer. (UICC, 2020).

2-7 Types of Cancers by Site

When plasma cells become cancerous and proliferate uncontrollably, it is called multiple myeloma. In this condition, the plasma cells produce an abnormal protein (antibody), referred to by several names, including monoclonal immunoglobulin, monoclonal protein (M-protein), or M-spike (NIH, 2023):

2-7-1 Lung Cancer:

Lung cancer is the leading cause of cancer-related deaths worldwide, with approximately 1.8 million deaths in 2020. It is often hard to detect early, as symptoms, such as a persistent cough, blood-stained sputum, chest pain, and recurring pneumonia or bronchitis, typically appear only after the disease has progressed (NIH, 2023).

In Iraq, lung cancer is the most commonly diagnosed cancer among males (16.7%) and the fifth most common among females (4.2%), according to the national survey conducted from 1995 to 2015 (Al-Khateeb and Mahd,2022). In the U.S., lung cancer is the second most common cancer and the leading cause of cancer deaths. While tobacco smoking is the primary risk factor, responsible for 80% to 90% of cases, other factors are also linked to lung cancer development (Schabath and Cote,2019). There are two main types of lung cancer.

2-7-1-A Non-small cell lung cancer:

Non-small cell lung cancer (NSCLC) makes up about 85% of all lung cancers and encompasses several histological types, including squamous cell carcinoma, adenocarcinoma, and large cell carcinoma (Hanna *et al.*, 2021).

2-7-1-b Small cell lung cancer:

Small cell lung cancer (SCLC) makes up around 15% of all lung cancers and is known for its rapid growth, tendency to metastasize early, and poor prognosis. SCLC is closely linked to exposure to carcinogenic tobacco substances, and the majority of patients are diagnosed with metastatic disease, with only one-third having the disease at an early, treatable stage (Rudin *et al.*, 2021).

2-7-2 Breast Cancer:

Breast cancer is one of the most common and deadly cancers among women globally. It often starts as a localized disease but can spread to areas like the lymph nodes, bones, and spine. Risk factors include age, alcohol consumption, and the use of oral contraceptives. Breast cancer makes up 23% of new cancer cases and 14% of cancer-related deaths. Diagnosis typically begins with a physical exam, followed by mammography or ultrasound for confirmation. Early detection and identifying mutations are key to providing effective treatments, as breast cancer is curable when diagnosed early. Treatment options include chemotherapy, hormonal therapy, radiation therapy, gene therapy, and other approaches (Jaheranee and Ejanga, 2020).

2-7-3 Prostate Cancer:

Prostate cancer is the second most common cancer in men and the fifth leading cause of death globally. In its early stages, it may be asymptomatic and often progresses slowly, requiring active surveillance. In 2018, there were 1,276,106 new cases of prostate cancer worldwide, with higher prevalence in developed countries. While there is no proven way to prevent prostate cancer, risks can be reduced by limiting fatty foods, eating more fruits and vegetables, and exercising. Men with a family history should consider screening at age 45. Common symptoms include difficulty urinating and nocturia, with advanced stages potentially causing urinary retention and back pain due to bone metastases. Understanding risk factors is key to improving screening and prevention (Rawla, 2019). In 2020, we observe an increase in the number of men diagnosed with prostate cancer, which remains in second place after lung cancer.

The identification of biomarkers such as the prostate-specific antigen (PSA) test, which is positively associated with the diagnosis of prostate cancer, has revolutionized the epidemiology of this disease (Mottet *et al.*, 2017).

The prostate-specific antigen (PSA) test is a blood test used to detect prostate cancer by measuring PSA levels. PSA is a protein produced by both cancerous and non-cancerous prostate tissues, mostly found in semen. While high PSA levels may indicate prostate cancer, other conditions like prostate enlargement or inflammation can also raise PSA levels (NCI, 2021).

Recent advances in genetic technologies have enabled a detailed analysis of genetic and epigenetic changes in prostate cancer, revealing key signaling pathways involved in its development. This research opens the door to new therapeutic approaches. However, more studies are needed to identify genes linked to prostate cancer risk and understand how specific genetic changes affect its progression. While no studies conclusively prove a direct link between diet and prostate cancer risk, many suggest a potential relationship (Rawla, 2019).

2-7-4 Skin Cancer:

The skin, the body's largest organ, consists of layers, with the epidermis (outer layer) and dermis (inner layer) being the main ones. Skin cancer originates in the epidermis, which contains three types of cells:

- Squamous cells: Thin, flat cells forming the outer layer.
- Basal cells: Round cells beneath the squamous cells.
- Melanocytes: Cells in the lower epidermis that produce melanin, responsible for skin color and darkening with sunlight exposure. (CDC, 2022).

Basal cell carcinoma and squamous cell carcinoma are the most common types of skin cancer, arising in the basal and squamous layers of the skin. Although treatable, they can lead to disfigurement and be costly to manage. Melanoma, the third most common type, causes the most deaths due to its tendency to spread. Most skin cancers result from excessive UV exposure from the sun, tanning devices, or sun lamps, which can damage skin cells, causing sunburn, premature aging, and potentially cancer over time (CDC,2022).

2-7-5 Cervical Cancer:

The uterus is a pouch in a woman's pelvis where a fertilized egg develops into a fetus and is protected until birth. Uterine cancer is one of the most common malignant tumors in women, and this cancer rarely occurs in women under the age of forty, while it frequently occurs after the age of sixty. Abnormal uterine bleeding is one of the symptoms of uterine cancer, and an endometrial biopsy is often used to confirm the diagnosis. While the exact causes of uterine cancer are not well understood, 10-25% of malignant tumors occur in women who received pelvic radiation for benign bleeding 5 to 25 years earlier. Risk factors for uterine cancer, like other cancers of this type, include diabetes, hypertension, obesity, and abnormal estrogen levels (SEER, 2023). Uterine cancer is considered the fourth most common type of cancer among women. The globally high mortality rate of uterine cancer can be reduced through a comprehensive approach that includes prevention, early diagnosis, effective screening, treatment programs, and providing emotional support to alleviate the pain experienced by patients with this disease. (Charity *et al.*,2019).

There are two types of uterine cancer:

2-7-5-A Endometrial cancer:

This type of cancer begins in the layer of cells that form the endometrium and is often detected at an early stage because it frequently results in abnormal vaginal bleeding. An abnormal increase in estrogen levels in a woman's body can lead to a higher risk of developing endometrial cancer. Other risk factors for endometrial cancer include irregular ovulation patterns, such as those seen in polycystic ovary syndrome, obesity, and diabetes. Additionally, increased estrogen intake after menopause raises the risk, as does starting menstruation early (before age 12) or experiencing late menopause, as the more menstrual cycles a woman has, the more her endometrium is exposed to estrogen. Age also plays a significant role in this disease; the older a woman is, the higher her chances of developing it. If endometrial cancer is detected early, surgical hysterectomy often treats this disease. (MFMER,2021).

2-7-5-b Uterine sarcoma:

Uterine sarcoma is a condition where malignant (cancerous) cells develop in the muscles or other supportive tissues of the uterus. The risk of developing this cancer is higher in women who have had prior radiation exposure to the pelvic area, though it is less common than endometrial cancer (NCI, 2022).

2-7-6 Colorectal Cancer:

Colorectal cancer, which includes both colon and rectal cancer, is the third most common cancer worldwide. In 2020, there were an estimated 1.93 million new cases and 935,173 deaths (IARC,2020).

Colon cancer originates in the large intestine (colon) and is most common in older adults, though it can occur at any age. It typically begins as benign polyps that can gradually transform into cancer. Because polyps are usually small and symptomless, regular screenings are recommended to detect and remove them early. Colon cancer treatment options include surgery, radiation therapy, and medications such as chemotherapy, targeted therapy, and immunotherapy. Colon cancer is sometimes referred to as colorectal cancer, which includes both colon and rectal cancer, as shown in Figure (2-4) (MFMER,2022).

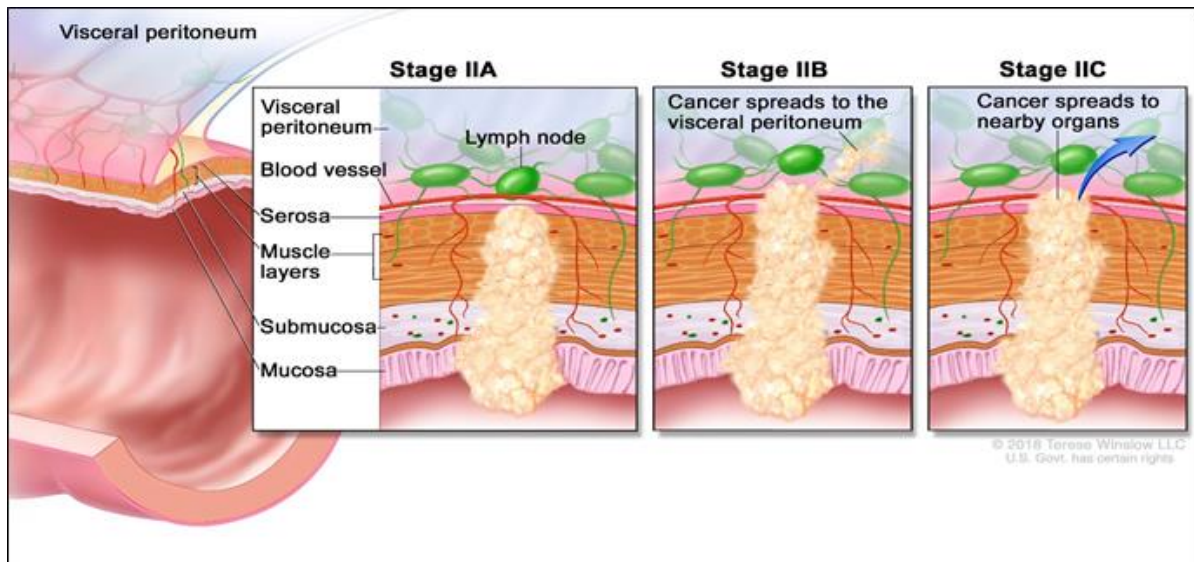


Figure (2-4) stages of the development of colorectal cancer (Terese Winslow LLC , 2018).

2-8 Cancer Prevention:

Cancer prevention is a measure taken to reduce the chance of developing cancer. By preventing cancer, the number of new cases is reduced, This, in turn, reduces the number of deaths. Cancer is a group of related diseases influenced by factors such as genetics, lifestyle, and the environment. Scientists are exploring several strategies to prevent cancer, including:

- ✓ A. Avoiding or controlling known carcinogens.
- ✓ B. Adopting healthier diets and lifestyles.
- ✓ C. Early detection of precancerous conditions.
- ✓ D. Chemoprevention (using medications to treat precancerous conditions or prevent cancer).

2-9 New procedures for cancer treatment:

Cancer is a global health issue responsible for one in six deaths worldwide. Cancer treatment has been extremely complex, and Traditional treatments like surgery, chemotherapy, and radiation therapy have been widely used. Recently, significant advancements have been made, including stem cell therapy, targeted therapy, ablation therapy, nanoparticles, natural antioxidants, radioactive materials, dynamic chemotherapy, and sonodynamic therapy. Current oncology methods focus on developing safe, effective nanomedicines for cancer treatment. Stem cell therapy shows promise in repairing damaged tissues and targeting tumors, while nanoparticles offer new diagnostic and therapeutic options. Targeted therapy can inhibit cancer cell growth with minimal damage to healthy cells. Ablation therapy, a minimally invasive technique, treats tumors by burning or freezing them. Antioxidants help neutralize free radicals, potentially preventing or treating cancer. Many new techniques are under clinical research, with some already approved (Debela *et al.*, 2021).

2-9-1 Nanoparticles

Nanoparticles (NPs) are particles with at least one dimension smaller than 100 nm, displaying unique properties that distinguish them from bulk materials of the same substance. These nanoparticles can be categorized as 0D, 1D, 2D, or 3D based on their shape. Nanoparticles have a very complicated basic composition this includes the surface layer, the shell layer, and the core, which is the central component of the NP and is commonly referred to as the NP itself. (Ali *et al.*, 2024). The remarkable characteristics of these materials, such as their high surface-to-volume ratio, dissimilarity, sub-micron size, and improved targeting mechanism, have made them highly significant in multidisciplinary fields. Nanoparticles (NPs) can penetrate deep into tissues, Enhancing the permeability and retention (EPR) effect, their surface properties also influence bioavailability and half-life by effectively traversing epithelial fenestration (Shin *et al.*, 2016).

2-9-2 Nanoparticles in Cancer Therapy

Nanotechnology offers a promising solution to address the limitations of molecular chemotherapies, such as poor targeting, drug resistance, and severe side effects. The key benefit of using nanoparticles (NPs) for treating metastasis is their ability to extend circulation time, preventing premature clearance or degradation of drugs. By increasing their ability to reach and accumulate at metastatic sites, the small size of NPs enables them to penetrate tumors and target residual cancer cells. NPs can also target circulating tumor cells (CTCs), accumulate in affected tissues or lymph nodes, and help inhibit cancer growth. Furthermore, theranostic NPs, which integrate both diagnostic and therapeutic functions, have garnered significant attention in recent research (Hegde et al., 2023). Various types of nanoparticles (NPs) are used in cancer therapy, including organic, inorganic, and hybrid NPs. Organic NPs include liposome-based, polymer-based, and dendrimer NPs. Inorganic NPs consist of gold NPs (Au NPs), carbon nanotubes, silica NPs, and quantum dots. Hybrid NPs integrate the advantages of various types, such as lipid-polymer hybrid NPs, organic-inorganic hybrid NPs, and cell membrane-coated NPs. (Cui et al., 2017). (Fig.5).

NPs used extensively in drug delivery systems include organic NPs, inorganic NPs, and hybrid NPs.

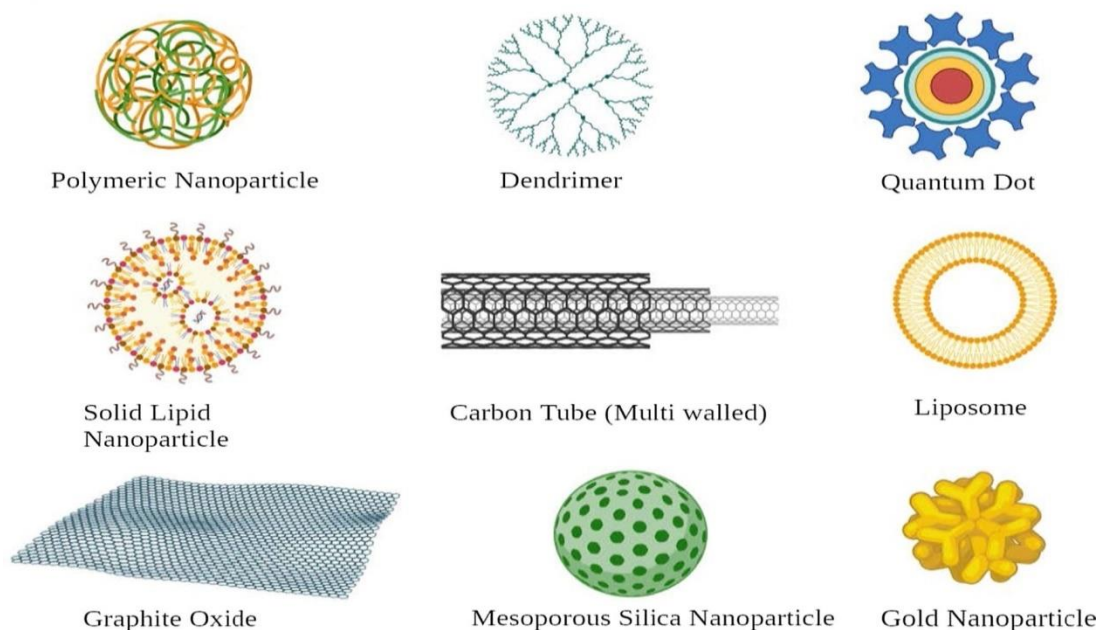


Figure (5) Different types of nanoparticles (NPs) for cancer therapy

2-9-3 General Requirements for Nanoparticles in Drug Delivery

For a cancer therapy system to be effective, nanoparticles need to possess certain qualities, such as being stable in physiological settings, biocompatible, and having a high bioavailability. Additionally, Nanoparticles must specifically target tumor cells without damaging surrounding healthy cells and release their payload upon reaching the target site. These properties are influenced by the physicochemical characteristics of the nanoparticles used for drug delivery. (Lungu et al., 2019) (Figure 6). The size distribution of the nanoparticles has a significant impact on how well they work in cancer treatments; they can be made to be both large enough to avoid extravasation from healthy blood vessels and small enough to enter the tumor, preventing agglomeration in other body parts. Since smaller particles (less than 50 nm) have higher antitumoral efficacy rates than larger ones, a variety of studies have been conducted to determine the ideal size of nanoparticles for usage in cancer treatment (Raju et al., 2015). The form of nanoparticles affects fluid dynamics, among other things, which has an impact on cancer treatment. Additionally, it is mentioned that the form of the particle affects whether the reticuloendothelial system (RES) absorbs the nanoparticles (Wen et al., 2023). Surface charge, porosity, flaws, and chemical group changes are some of the relatively complicated processes that make up surface chemistry. Surface chemistry affects several aspects of the system, including cellular absorption, degradation and agglomeration rates, and surface

interactions. According to certain research, for example, a positively charged surface increases the likelihood of cellular absorption (Tran *et al.*, 2017). Nonetheless, distinct surface characteristics may be needed for various cancer kinds or stages of the same cancer type (Lungu *et al.*, 2019).

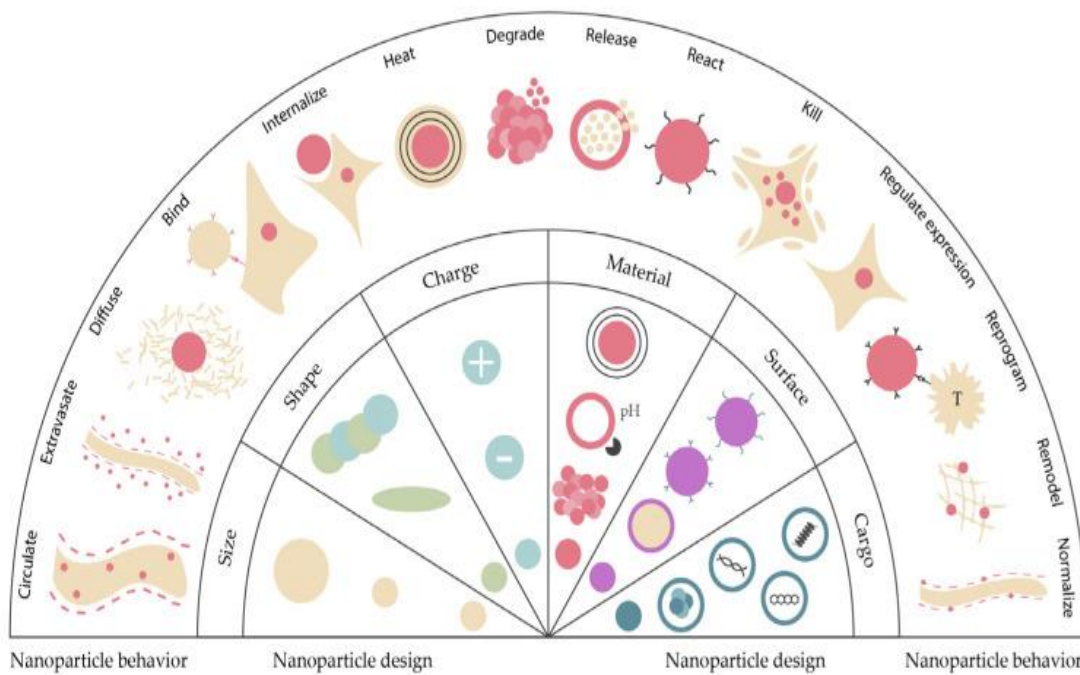


Figure (6) the behavior of nanoparticles within cells, their different interactions throughout the body, and their physicochemical characteristics (Hauert *et al.* , 2014).

2-9-3 Mechanisms of Targeting

The ability of nanocarriers to preferentially target cancer cells is essential for medication delivery because it improves therapeutic efficacy while shielding healthy cells from damage. Understanding tumor biology and the interaction between nanocarriers and tumor cells is essential to better addressing the problems of tumor targeting and the creation of nanocarrier systems. Passive targeting and active targeting are the two main categories into which the targeting methods fall. See Figure 7 (Sell, 2023).

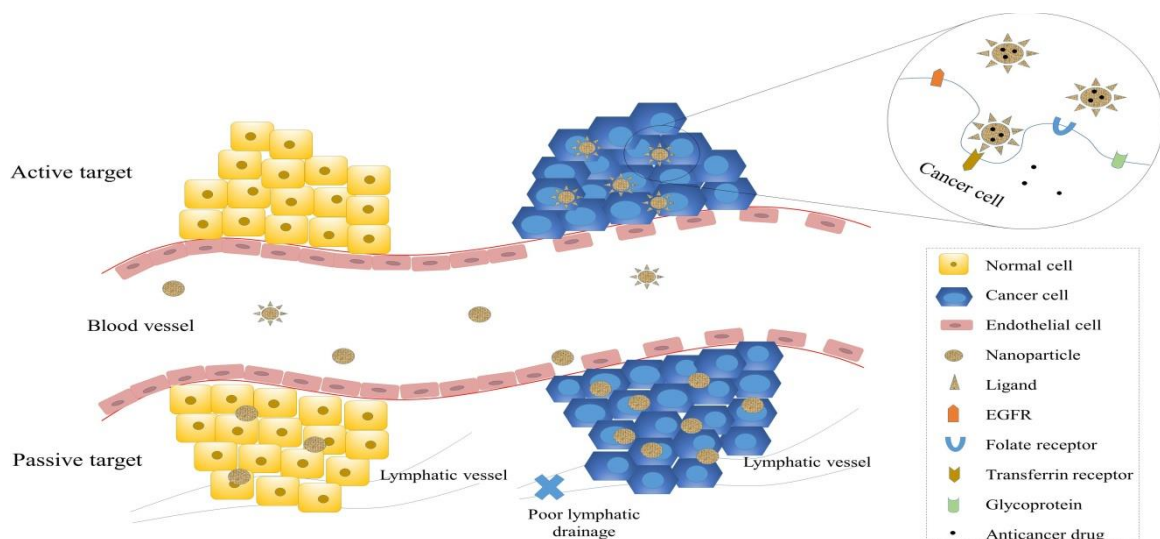


Figure (7) Passive and active targeting of NPs to cancer cells

Conclusion

Cancer continues to pose a significant threat to global health, exacerbated by disparities in care delivery due to systemic challenges and resource limitations. Traditional therapies, while effective to some extent, are hindered by severe side effects and lack of specificity, underscoring the need for

innovative solutions. Nanotechnology offers a promising alternative, leveraging the unique properties of nanoparticles to enhance drug delivery, minimize toxicity, and target cancer cells with precision. By tailoring nanotherapeutics to the tumor microenvironment, treatment efficacy is significantly improved, providing a viable pathway to overcoming current limitations. Advancing the use of nanoparticles in cancer care requires robust research, interdisciplinary collaboration, and equitable healthcare systems to ensure these innovations benefit all patients, regardless of geography or socioeconomic status. Numerous therapeutic nanoformulations have created new avenues for the treatment of cancer. Various types of NPs have demonstrated enhanced drug delivery efficacy, biocompatibility, tumor targeting, stability, reduced systemic toxicity, and the ability to overcome drug resistance. The development of advanced nanoparticles for cancer treatment could address the limitations of traditional therapies and offer hope for cancer patients in the future.

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