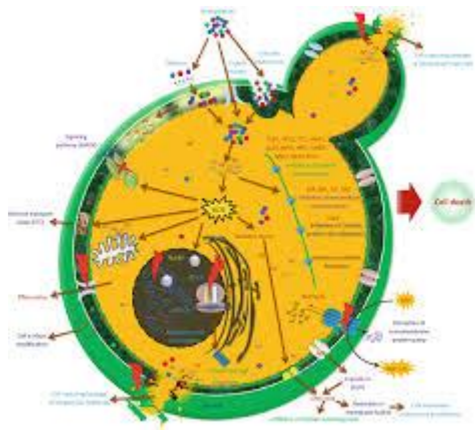
Department of Biotechnology

2025-2026

Nanotechnology

Stage (Second)

Lec. (6)



Role of nanobiotechnology in the infectious and noninfectious diseases

By

Dr. Sarah Kamil

sarah.kamil@uomus.edu.iq

Nanotechnology is the study of and creation of new technologies at the molecular and atomic levels, or roughly 1–100 nm, or a billionth (10–9) of a metre [1]. It is used to understand the basics of phenomena to create structures, systems, and devices at the nanoscale with multiple functions. In the eighties, when the scanning electron microscope was developed, it was the main reason for the launch of nanotechnology. Four disciplines are included in nanotechnology: chemistry, physics, engineering, and biology.

Nanotechnology offers a broad spectrum of applications:-

1. Medicine and health.
2. Energy and environment.
3. Transport.
4. Electronic Engineering.
5. Space Exploration.
6. Food.

Applications of Nanotechnology in the Medical Field:

The applications of nanotechnology in the medical field are called nanomedicine. These applications are considered the most important potential applications of nanotechnology, which include:

1. Biological labels
2. Gene and drug delivery .
3. Protein detection .
4. DNA structural investigation [12], [13].
5. Tissue engineering .
6. Thermal cancer therapy (hyperthermia) .
7. Pathogen detection .

Nanomedicine

Nanomedicine has gained great interest in medical settings due to the wide range of possible applications it can offer. Nanomedicine applications concern biological tags, protein/DNA analysis, gene/drug delivery systems, pathogenic detection possibilities, disease diagnosis tools, tissue engineering, photothermal cancer therapy, enhancement of imaging, and toxicity examinations.

1. Role in Infectious Diseases (Communicable)

In the realm of infectious diseases, nanobiotechnology addresses the twin crises of **antimicrobial resistance (AMR)** and **emerging viral pathogens**.

- **Nano-Antibiotics & Antimicrobials:** Nanoparticles (NPs) made of silver, gold, and chitosan possess inherent antimicrobial properties. Unlike traditional antibiotics, they physically disrupt bacterial membranes or damage microbial DNA, making it nearly impossible for pathogens to develop resistance.
- **Next-Gen Vaccinology:** The success of mRNA-LNP (lipid nanoparticle) technology has expanded. By 2026, researchers are using these "nano-envelopes" to deliver vaccines for malaria, tuberculosis, and HIV, protecting the fragile genetic cargo from degradation by the body's immune system before it reaches the target cells.
- **Rapid Diagnostics:** Nanobiosensors can now detect viral loads (like SARS-CoV-2 or Influenza) at much lower concentrations than traditional PCR, often in minutes. Techniques using **Quantum Dots** provide high-contrast imaging of how a virus enters a cell, facilitating the design of better blocking agents.

2. Role in Noninfectious Diseases

Chronic diseases, such as cancer and heart disease, benefit from the precision of "targeted delivery," which minimizes systemic side effects (like the hair loss or nausea associated with chemotherapy).

Cancer (Oncology)

- **Targeted Chemo:** Nanocarriers are engineered to recognize specific biomarkers on tumor surfaces. This allows drugs like Paclitaxel (Abraxane) to accumulate only in the tumor, leaving healthy tissue untouched.
- **Theranostics:** This is a 2026 "mega-trend" where a single nanoparticle both **diagnoses** the tumor (via imaging) and **treats** it simultaneously.
- **Nanobodies:** By 2026, nanobody-based therapies (miniaturized antibodies) are being used to penetrate dense solid tumors that traditional antibodies are too large to enter.

Cardiovascular Diseases

- **Plaque Targeting:** Nanoparticles are being designed to seek out and dissolve atherosclerotic plaques in arteries.
- **Regenerative Scaffolds:** Nanofibers act as "scaffolding" to help grow new heart tissue after a myocardial infarction (heart attack).
- **Nanozymes:** These are synthetic nanoparticles that mimic natural enzymes, used to reduce inflammation in blood vessels and protect against heart failure.

Feature	Infectious Diseases	Noninfectious Diseases
Primary Goal	Pathogen eradication & prevention	Targeted therapy & tissue repair
Key Mechanism	Membrane disruption / Vaccine delivery	Biomarker targeting / Controlled relea
Common Materials	Silver NPs, Lipid Nanoparticles (LNPs)	Polymeric NPs, Carbon Dots, Liposome
2026 Breakthrough	Multi-pathogen mRNA vaccines	Mechanically-aware "smart" drug release

1. Smart Targeting in Cancer Therapy (The "Magic Bullet")

In traditional medicine, drugs circulate systemically, affecting healthy cells and causing toxicity. Nanotechnology bypasses this through two distinct mechanisms:

A. Passive Targeting (The EPR Effect)

Tumors grow rapidly and create "leaky" blood vessels with microscopic gaps.

- **Mechanism:** Nanoparticles (NPs) are engineered to a specific size (usually **10–100 nm**). They are too large to escape healthy blood vessels but small enough to slip through the "leaks" in tumor vessels and accumulate there. This is known as the **Enhanced Permeability and Retention (EPR)** effect.

B. Active Targeting (Molecular Recognition)

This adds a "GPS" to the nanoparticle.

- **Mechanism:** The surface of the NP is coated with **ligands** (antibodies or peptides) that specifically bind to receptors found *only* on the surface of cancer cells.
- Once the NP docks onto the cancer cell, the cell "swallows" it (endocytosis), and the drug payload is released directly into the nucleus or mitochondria, destroying the cell from within.

2. Nanodiagnostics: Catching Disease Before Symptoms

In 2026, we no longer wait for a tumor to grow to be visible on an X-ray. We detect the "molecular signatures" of disease.

A. Quantum Dots (QDs)

These are semiconductor nanocrystals that glow intensely under specific light.

- **Application:** QDs are used as "biological flares." By attaching them to cancer-seeking molecules, surgeons can see exactly where a tumor begins and ends in real-time during surgery, ensuring no malignant tissue is left behind.

B. Lab-on-a-Chip (LOC)

This technology shrinks a full-scale diagnostic lab onto a single microchip.

- **Mechanism:** Using **nanofluidics**, a single drop of blood is pushed through channels thinner than a human hair. Sensors can identify DNA sequences of viruses or specific "circulating tumor cells" (CTCs) in minutes. This allows for **Point-of-Care (POC)** testing, where diagnosis happens in the doctor's office, not a remote lab.

3. Remote-Controlled "Nanorobots"

One of the most exciting 2026 frontiers is **stimuli-responsive** delivery.

1. **Magnetic Steering:** NPs containing iron oxide are injected into the patient. Doctors use external magnetic fields to "drive" the medicine through the bloodstream to a specific site (like a brain clot).
2. **Triggered Release:** Once the NPs reach the target, they are hit with an external trigger—like **ultrasound** or **Near-Infrared (NIR) light**. This causes the NP to heat up or vibrate, breaking its shell and releasing the drug exactly where it's needed.