BT405 – NANO BIOTECHNOLOGY

MID TERM MOST IMPORTANT QUESTIONS

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GROUP LINK: https://chat.whatsapp.com/BjC6W0jZx8o9yaC2ISh1Gu

1. What are diatoms?

Diatoms are microscopic, single-celled algae characterized by intricate, silica-based cell walls known as frustules. These frustules exhibit highly ordered nanoscale patterns and pores, making them valuable natural nanostructures. Diatoms are photosynthetic and found in both freshwater and marine environments, contributing significantly to global oxygen production and carbon fixation.

Their silica structures are biocompatible, chemically stable, and can be functionalized, making them useful in applications like biosensing, drug delivery, photonic devices, and as templates for nanofabrication. Their natural ability to self-assemble silica under ambient conditions also provides insights for developing sustainable nanomanufacturing techniques.

2. What are Affinity Binding Receptors?

Affinity binding receptors are biomolecules—typically proteins, peptides, or engineered nanostructures—that specifically recognize and bind to target molecules (ligands) with high affinity and selectivity. They exploit molecular recognition principles such as hydrogen bonding, van der Waals forces, electrostatic interactions, and hydrophobic effects to achieve this binding.

These receptors are integral to the design of nanoscale biosensors, targeted drug delivery systems, and diagnostic tools. Common examples include antibodies, aptamers, lectins, and engineered receptor proteins. When immobilized on nanoparticles, nanostructured surfaces, or within nanoarrays, they enable precise detection or capture of biomarkers, pathogens, or toxins with high sensitivity and specificity.

3. What are Intrinsic and Extrinsic Factors effecting Nanocomposites?

Intrinsic Factors

1. ***Nanofiller Type and Morphology:*** Shape (e.g., nanotubes, nanospheres, nanorods), size, and aspect ratio of the nanomaterials (like graphene, carbon nanotubes, or silica nanoparticles) directly affect mechanical strength, electrical conductivity, and surface area.
2. ***Matrix Material:*** The chemical nature and mechanical properties of the base material (e.g., polymers, ceramics, or biopolymers) determine the compatibility and overall behavior of the nanocomposite.

3. ***Interfacial Interaction:*** The strength of bonding (covalent or non-covalent) between the nanofillers and the matrix affects load transfer, stability, and durability.
4. ***Dispersion Quality:*** Uniform distribution of nanoparticles avoids agglomeration and ensures consistent nanoscale properties across the composite.
5. ***Functionalization of Nanoparticles:*** Surface modification (e.g., with ligands, polymers, or biomolecules) enhances compatibility and adds specific functionalities like targeting or sensing.

Extrinsic Factors:

1. ***Synthesis Method:*** Techniques like sol-gel, electrospinning, or in-situ polymerization influence morphology, crystallinity, and homogeneity.
2. ***Processing Conditions:*** Temperature, pH, solvent choice, and mixing techniques affect nanoparticle stability, alignment, and integration.
3. ***Environmental Conditions:*** Exposure to humidity, temperature fluctuations, radiation, or reactive chemicals can alter performance and degrade the nanocomposite over time.
4. ***Mechanical Stress:*** External mechanical forces during application or testing can impact structural integrity and reveal composite toughness or brittleness.

4. Write role of Biosensors in food.

Biosensors play a vital role in food by enabling rapid, sensitive, and specific detection of contaminants, quality indicators, and nutritional content. Their integration into food systems enhances safety, shelf-life assessment, and traceability. Key roles include:

1. ***Pathogen Detection:*** Biosensors identify harmful microorganisms like *E. coli*, *Salmonella*, and *Listeria* in food products, preventing foodborne illnesses.
2. ***Toxin and Allergen Monitoring:*** They detect chemical toxins (e.g., mycotoxins, pesticide residues) and allergens (e.g., gluten, peanuts), ensuring regulatory compliance and consumer safety.
3. ***Freshness and Spoilage Indicators:*** Enzyme- or microbial-based biosensors can assess changes in metabolites (e.g., amines, organic acids) to indicate spoilage or degradation.
4. ***Nutrient Analysis:*** Biosensors quantify levels of sugars, vitamins, and amino acids, supporting nutritional labeling and quality control.
5. ***Authentication and Adulteration Detection:*** They help verify product authenticity (e.g., pure olive oil, honey) and detect adulterants or mislabeling.
6. ***Packaging Integration:*** Smart packaging with embedded biosensors provides real-time monitoring of food condition during storage and transport.

5. Write use of Nanotechnology in food.

Nanotechnology is used in food to improve safety, quality, shelf life, and nutritional value through nanoscale innovations in processing, packaging, and delivery systems. Key applications include:

1. ***Nano-Encapsulation:*** Encapsulates nutrients, flavors, or bioactive compounds in nanocarriers (like liposomes or polymeric nanoparticles) to enhance stability, solubility, and controlled release in the body.

2. ***Food Packaging:*** Incorporates nanomaterials such as silver nanoparticles or nanoclays into packaging to provide antimicrobial properties, barrier enhancement, and environmental responsiveness (e.g., indicating spoilage or contamination).
3. ***Nanosensors for Quality Monitoring:*** Detect pathogens, toxins, or spoilage indicators in food products in real time, enabling rapid, on-site testing and monitoring.
4. ***Nano-Emulsions:*** Improve the texture, appearance, and bioavailability of ingredients like vitamins, essential oils, or antioxidants in beverages and functional foods.
5. ***Food Fortification:*** Delivers micronutrients (e.g., iron, zinc) in nano-sized forms to improve absorption and minimize sensory changes in fortified foods.
6. ***Anti-Caking and Flavor Enhancement:*** Nano-coatings prevent clumping in powders and enhance flavor release or aroma in processed foods.
7. ***Smart Delivery Systems:*** Target the release of compounds (such as probiotics or therapeutic agents) at specific sites in the gastrointestinal tract.

6. Write applications of Liquid Crystal.

Liquid crystals have unique properties that combine fluidity with anisotropic molecular ordering, making them highly versatile in various applications. Key applications include:

1. ***Biosensing:*** Used as sensitive transducers in biosensors, liquid crystals change orientation in response to biomolecular interactions (e.g., binding of proteins, DNA, or toxins), enabling label-free detection.
2. ***Food Safety Monitoring:*** Detect bacterial contamination or spoilage by responding to metabolic byproducts, providing visual or optical changes in smart packaging.
3. ***Drug Delivery Systems:*** Serve as nanocarriers with tunable structures (e.g., cubic or hexagonal phases) to control the release rate and target delivery of pharmaceuticals or nutraceuticals.
4. ***Display Technologies:*** Widely used in LCDs (Liquid Crystal Displays) for screens, exploiting their ability to modulate light based on electric field-induced orientation.
5. ***Smart Coatings and Films:*** Applied in responsive surfaces or films that react to environmental stimuli (temperature, pH, light), useful in packaging and sensors.
6. ***Optical Devices:*** Employed in tunable lenses, optical switches, and light modulators due to their birefringence and responsive optical properties.
7. ***Biomedical Imaging:*** Used in label-free detection and imaging techniques where changes in liquid crystal alignment indicate presence of analytes or biological events.

7. Explain self-resemblance.

Self-resemblance refers to the property where a structure or pattern repeats itself at different scales, showing similar features whether you zoom in or out. In nanobiotechnology, this concept is closely related to self-similarity and often connects to fractal-like structures found in biological systems.

For example, many natural nanostructures—like the branching patterns of blood vessels, DNA folding, or surface textures of diatoms—exhibit self-resemblance. This hierarchical repetition enables efficient packing, enhanced surface area, or optimized mechanical and functional properties.

In nanobiotechnology, exploiting self-resemblance helps design biomimetic materials and devices that mimic these multi-scale patterns, improving interactions with biological systems and enhancing properties like strength, catalytic activity, or molecular recognition.

8. Write characteristics of bio receptors.

Bio-receptors possess several key characteristics that make them essential for selective and sensitive molecular recognition in nanobiotechnology:

1. ***High Specificity:*** They bind selectively to a particular target molecule (ligand), such as a protein, nucleic acid, or small molecule, minimizing non-specific interactions.
2. ***High Affinity:*** They form strong, stable complexes with their targets, enabling detection at very low concentrations.
3. ***Biocompatibility:*** Naturally derived or engineered to function effectively in biological environments without causing adverse reactions.
4. ***Reversibility:*** Many bio-receptors can bind and release their ligands, allowing repeated use in sensing or separation applications.
5. ***Structural Stability:*** Maintain their functional three-dimensional conformation under physiological or processing conditions to ensure consistent performance.
6. ***Versatility:*** Include a wide range of molecules such as antibodies, enzymes, aptamers, nucleic acids, and peptides, allowing tailoring to specific targets.
7. ***Rapid Response:*** Enable quick binding interactions, supporting real-time detection or signaling.

9. What are biosensors?

Biosensors are analytical devices that combine a biological recognition element with a physical or chemical transducer to detect specific biological molecules or chemical substances. The biological element—such as enzymes, antibodies, nucleic acids, or cells—selectively interacts with the target analyte, while the transducer converts this interaction into a measurable signal (electrical, optical, thermal, or mechanical).

In nanobiotechnology, biosensors leverage nanomaterials like nanoparticles, nanotubes, or nanowires to enhance sensitivity, reduce detection limits, and enable real-time monitoring. They are widely used for detecting pathogens, toxins, biomarkers, and environmental pollutants with high specificity and rapid response, making them valuable tools in healthcare, food safety, environmental monitoring, and biotechnology.

10. What are applications of metal nanotubes in environment?

Metal nanotubes have several impactful applications in environmental fields due to their unique properties like high surface area, conductivity, and catalytic activity:

1. ***Pollutant Detection and Sensing:*** Metal nanotube-based sensors detect trace amounts of heavy metals, pesticides, and toxic gases in air and water with high sensitivity and selectivity.
2. ***Catalytic Degradation:*** They serve as catalysts or catalyst supports for breaking down organic pollutants, dyes, and harmful chemicals in wastewater treatment through advanced oxidation processes.
3. ***Water Purification:*** Incorporated into filtration membranes or adsorbents, metal nanotubes enhance removal of contaminants like heavy metals, pathogens, and organic toxins by adsorption or catalytic transformation.
4. ***Energy-efficient Environmental Remediation:*** Used in photocatalysis or electrocatalysis to convert pollutants into less harmful substances using solar or electrical energy, enabling greener cleanup methods.

5. ***Environmental Monitoring:*** Integrated into portable, nanoscale devices for continuous monitoring of environmental parameters, enabling rapid response to pollution events.
6. ***Gas Capture and Storage:*** Their high surface area and tunable chemistry allow efficient capture of greenhouse gases (e.g., CO_2) for mitigation efforts.

11. What are applications of carbon nanotubes?

Carbon nanotubes (CNTs) have diverse applications due to their exceptional mechanical strength, electrical conductivity, thermal stability, and large surface area:

1. ***Biosensors:*** CNTs enhance sensitivity and electron transfer in sensors detecting biomolecules, pathogens, or toxins.
2. ***Drug Delivery:*** Used as nanocarriers for targeted delivery and controlled release of drugs, improving therapeutic efficacy and reducing side effects.
3. ***Tissue Engineering:*** Serve as scaffolds promoting cell growth and differentiation due to their biocompatibility and mechanical properties.
4. ***Environmental Remediation:*** Adsorb pollutants like heavy metals and organic toxins from water and air; act as catalysts in pollutant degradation.
5. ***Energy Storage:*** Incorporated in batteries and supercapacitors to improve charge capacity and cycling stability.
6. ***Electronics and Nanodevices:*** Used in transistors, conductive films, and nanoscale circuits owing to their excellent electrical properties.
7. ***Composite Materials:*** Reinforce polymers and ceramics to enhance strength, flexibility, and durability in aerospace, automotive, and sports equipment.
8. ***Water Purification:*** Integrated into membranes for efficient filtration and removal of contaminants.

12. What are Nano filters?

Nanofilters are filtration systems that use nanoscale materials or structures to remove contaminants from liquids or gases with extremely high precision. Their pores or active sites typically range from 1 to 100 nanometers, allowing selective separation based on size, charge, or chemical affinity. Key features include:

- ***High Selectivity:*** Capable of filtering out viruses, bacteria, heavy metals, organic molecules, and nanoparticles.
- ***Large Surface Area:*** Nanomaterials like graphene oxide, carbon nanotubes, or nanoporous membranes provide extensive active sites for adsorption or filtration.
- ***Enhanced Permeability:*** Nanoscale channels allow rapid flow while maintaining filtration efficiency.
- ***Functionalization:*** Surfaces can be chemically modified to target specific contaminants or improve anti-fouling properties.

13. What are applications of Nanotechnology?

Nanotechnology finds applications across a vast range of fields due to its ability to manipulate matter at the molecular and atomic scale, enhancing material properties and enabling novel functionalities:

1. ***Medicine and Healthcare:*** Targeted drug delivery, improved imaging and diagnostics, biosensors for disease detection, regenerative medicine, and development of nanorobots for surgery.

2. ***Electronics:*** Development of smaller, faster, and more efficient transistors, memory devices, flexible electronics, and quantum computing components.
3. ***Energy:*** Enhanced solar cells, high-capacity batteries and supercapacitors, fuel cells, and catalysts for clean energy production and storage.
4. ***Environment:*** Water purification using nanofiltration, pollutant detection and removal, air filtration, and environmental remediation through nanoscale catalysts.
5. ***Food Industry:*** Nano-encapsulation of nutrients, smart packaging for freshness monitoring, improved food safety sensors, and texture enhancement.
6. ***Materials Science:*** Stronger, lighter, and more durable composites, self-healing materials, anti-corrosive coatings, and conductive inks.
7. ***Cosmetics:*** Improved UV protection, controlled release of active ingredients, and enhanced skin absorption.
8. ***Agriculture:*** Nano-fertilizers, targeted pesticide delivery, and sensors for soil and crop health monitoring.

14. What features are required for a Nano receptor?

A nano receptor should have the following key features to function effectively at the nanoscale:

1. ***High Specificity:*** Ability to selectively recognize and bind a particular target molecule among many similar entities.
2. ***High Affinity:*** Strong binding interactions to ensure stable and sensitive detection or capture of the target, even at low concentrations.
3. ***Biocompatibility:*** Compatibility with biological systems to avoid toxicity or immune reactions when used in vivo or in biological environments.
4. ***Structural Stability:*** Maintain functional conformation under varying physiological or environmental conditions (pH, temperature, ionic strength).
5. ***Rapid Binding Kinetics:*** Fast association and dissociation rates for real-time sensing or controlled release applications.
6. ***Reversibility:*** Ability to release the bound target if needed, allowing reuse or dynamic interactions.
7. ***Functionalizability:*** Capability to be chemically modified or engineered with tags, labels, or linkers for integration into nanodevices.
8. ***Nanoscale Size and Geometry:*** Suitable dimensions and shape to fit within nanosystems and interact effectively with nanoscale targets.

15. What are Nanofibers? Write their uses.

Nanofibers are ultra-thin fibers with diameters typically ranging from tens to a few hundred nanometers. They have a high surface-area-to-volume ratio, excellent mechanical properties, and porosity, making them valuable in various applications.

Uses of Nanofibers:

1. ***Biomedical Applications:*** Used as scaffolds for tissue engineering, wound dressings, and drug delivery systems due to their biocompatibility and ability to mimic natural extracellular matrices.
2. ***Filtration:*** Highly efficient in air and water filtration systems, removing fine particles, bacteria, and viruses thanks to their small pore sizes.
3. ***Sensors:*** Incorporated into biosensors and chemical sensors for enhanced sensitivity and rapid response.
4. ***Protective Clothing:*** Used in manufacturing lightweight, breathable, and protective fabrics with antimicrobial properties.
5. ***Energy Storage:*** Employed in battery separators, supercapacitors, and fuel cells for improved performance and durability.
6. ***Catalysis:*** Serve as supports for catalysts in chemical reactions, increasing active surface area and reaction rates.

16. Write applications of Nano filters.

Nano filters have diverse applications due to their ability to precisely filter particles at the nanoscale. Key applications include:

1. ***Water Purification:*** Remove bacteria, viruses, heavy metals, organic pollutants, and nanoparticles from drinking water and wastewater.
2. ***Air Filtration:*** Capture ultrafine particles, pollutants, allergens, and pathogens in air purification systems and masks.
3. ***Biomedical Applications:*** Used in dialysis, blood filtration, and sterilization processes to selectively remove toxins or pathogens.
4. ***Food and Beverage Industry:*** Filter out contaminants, improve shelf life, and enhance product safety by removing microbes and unwanted particles.
5. ***Pharmaceutical Industry:*** Purify drugs and vaccines by removing impurities and ensuring sterility.
6. ***Industrial Processes:*** Separate nanoscale particles or chemicals in chemical manufacturing, oil refining, and semiconductor fabrication.
7. ***Environmental Remediation:*** Capture and remove pollutants from industrial effluents or contaminated air.

17. Explain interaction of Nucleic Acid with biosensors.

Nucleic acids (DNA or RNA) interact with biosensors primarily through specific base-pairing and hybridization mechanisms, enabling highly selective detection of genetic material or related molecules. Here's how the interaction works:

1. ***Recognition Element:*** Single-stranded nucleic acids (probes) are immobilized on the biosensor surface. These probes are designed to be complementary to a target nucleic acid sequence.
2. ***Hybridization:*** When the target nucleic acid is present in a sample, it binds (hybridizes) specifically to the probe via complementary base pairing (A-T/U and G-C), forming a stable double-stranded structure.
3. ***Signal Transduction:*** This binding event induces a measurable change in the biosensor's physical or chemical properties—such as electrical conductivity, optical signals (fluorescence, color change), or mass changes.

4. ***Amplification and Detection:*** Some biosensors incorporate amplification steps (e.g., PCR, isothermal amplification) or nanomaterials (gold nanoparticles, carbon nanotubes) to enhance sensitivity and enable detection of very low concentrations.

18. Which Nanomaterials are used for coating?

Several nanomaterials are widely used for coatings due to their unique properties like enhanced mechanical strength, chemical resistance, antimicrobial activity, and optical effects. Common nanomaterials for coatings include:

1. **Nanoparticles:**
   - ***Silver nanoparticles:*** Known for strong antimicrobial and antifungal properties, used in medical devices and food packaging.
   - ***Titanium dioxide (TiO_2) nanoparticles:*** Provide UV protection, photocatalytic self-cleaning, and antimicrobial effects.
   - ***Zinc oxide (ZnO) nanoparticles:*** Offer UV blocking, antibacterial activity, and corrosion resistance.

2. **Carbon-based Nanomaterials:**
   - ***Graphene and graphene oxide:*** Enhance mechanical strength, electrical conductivity, and barrier properties.
   - ***Carbon nanotubes:*** Improve toughness and electrical/thermal conductivity.

3. **Nanoclays:**
   Enhance barrier properties against gases and moisture, improving durability in packaging and construction coatings.

4. **Silica nanoparticles:**
   Increase hardness, scratch resistance, and chemical stability.

5. **Quantum dots:**
   Used for coatings with tunable optical properties like color or fluorescence in displays and sensors.

6. **Polymeric nanomaterials:**
   Nanostructured polymers or polymeric nanoparticles add flexibility, anti-fouling, or controlled release functionalities.

19. Explain Surface Plasmon Resonance.

Surface Plasmon Resonance (SPR) is a sensitive optical technique used to study molecular interactions in real time without labeling. It relies on the excitation of surface plasmons—coherent oscillations of free electrons—at the interface between a metal (usually gold or silver) and a dielectric (like a biological sample). Here's how SPR works:

1. ***Surface Plasmons:*** When polarized light hits the metal surface at a specific angle, it excites surface plasmons, generating an evanescent electromagnetic wave confined near the surface.
2. ***Resonance Condition:*** This excitation causes a reduction in reflected light intensity at a characteristic angle (resonance angle) dependent on the refractive index near the metal surface.
3. ***Binding Detection:*** When molecules (e.g., proteins, nucleic acids) bind to receptors immobilized on the metal surface, the local refractive index changes, shifting the resonance angle.
4. ***Real-Time Monitoring:*** By measuring shifts in the resonance angle over time, SPR provides quantitative information on binding kinetics, affinity, and concentration without any fluorescent or radioactive labels.

20. Write properties of CNTs.

Carbon nanotubes (CNTs) have unique and remarkable properties that make them highly valuable in nanobiotechnology and other fields:

1. ***Mechanical Strength:*** Extremely high tensile strength (up to 100 times stronger than steel) and excellent elasticity.
2. ***Electrical Conductivity:*** Can behave as either metals or semiconductors depending on their structure (chirality), enabling diverse electronic applications.
3. ***Thermal Conductivity:*** Exceptional heat conduction, much higher than copper, useful for thermal management.
4. ***High Surface Area:*** Large surface-to-volume ratio facilitates efficient interactions with molecules and enhances catalytic or sensing abilities.
5. ***Chemical Stability:*** Resistant to chemical degradation under many conditions, ensuring durability.
6. ***Lightweight:*** Very low density, contributing to strength without adding weight.
7. ***Biocompatibility:*** With proper functionalization, CNTs can be made biocompatible for biomedical uses.
8. ***Unique Optical Properties:*** Exhibit photoluminescence and near-infrared absorption useful for imaging and sensing.

21. Explain that Gold particles (AuNPs) found significant exploitations in biomedical field.

Gold nanoparticles (AuNPs) have found significant applications in the biomedical field due to their unique physicochemical properties and biocompatibility:

1. ***Drug Delivery:*** AuNPs can be functionalized with drugs, targeting ligands, or antibodies, enabling targeted and controlled delivery to specific cells or tissues, which enhances therapeutic efficacy while minimizing side effects.
2. ***Imaging and Diagnostics:*** Their strong surface plasmon resonance enables enhanced contrast in imaging techniques like optical microscopy, photoacoustic imaging, and computed tomography. AuNPs are also used in biosensors for sensitive detection of biomarkers and pathogens.
3. ***Photothermal Therapy:*** AuNPs convert absorbed light into heat when irradiated with near-infrared light, selectively destroying cancer cells through localized hyperthermia without damaging surrounding healthy tissue.
4. ***Gene Therapy:*** Used as carriers to deliver genetic material (DNA, RNA) into cells efficiently and safely.

5. ***Antimicrobial Agents:*** Exhibit inherent antimicrobial activity and can be combined with other agents to fight infections.
6. ***Biocompatibility and Stability:*** AuNPs are non-toxic, easily synthesized in various sizes and shapes, and can be surface-modified for specific biomedical applications.

22. Explain Bioreactor.

A bioreactor is a controlled device or system designed to support and optimize biological reactions, typically involving living cells, tissues, or enzymes. It provides a suitable environment—such as temperature, pH, oxygen, nutrients, and agitation—to promote growth, metabolism, or production of desired biological products. In nanobiotechnology, bioreactors are used for:

- Cultivating microorganisms or cell cultures that produce nanoparticles, enzymes, or bioactive compounds.
- Synthesis of nanomaterials through biological routes using bacteria, fungi, or plant cells (green synthesis).
- Tissue engineering, where bioreactors support the growth of cells on scaffolds to develop functional tissues under dynamic conditions.
- Bioprocess scale-up, ensuring consistent, reproducible production of nanobiotechnological products.

23. Explain the intrinsic and extrinsic factors effecting the self-assembled nanomaterial.

Intrinsic Factors affecting self-assembled nanomaterials are inherent properties of the building blocks themselves, including:

1. ***Molecular Structure:*** Shape, size, and chemical functionality of the nanoparticles or molecules dictate how they pack and interact.
2. ***Surface Chemistry:*** Presence of functional groups, charge, and hydrophobic/hydrophilic balance influence inter-particle interactions.
3. ***Intermolecular Forces:*** Van der Waals forces, hydrogen bonding, electrostatic interactions, and π-π stacking govern the stability and arrangement of assemblies.
4. ***Flexibility and Rigidity:*** The structural flexibility of components affects the ability to form ordered or dynamic assemblies.
5. ***Polydispersity:*** Uniformity in size and shape promotes more regular and predictable self-assembly patterns.

Extrinsic Factors are external environmental conditions impacting the assembly process, such as:

1. ***Temperature:*** Influences kinetic energy and interaction strength, affecting assembly rate and structure.
2. ***pH:*** Alters ionization states and surface charges, modifying electrostatic interactions.
3. ***Solvent Properties:*** Polarity, ionic strength, and dielectric constant affect solubility and interaction forces.
4. ***Concentration:*** Determines the availability of building blocks for nucleation and growth of assemblies.
5. ***External Fields:*** Magnetic, electric, or mechanical forces can direct or influence the orientation and order of nanomaterials.

6. ***Time:*** Duration allowed for assembly can affect the size and perfection of the formed structures.

24. Explain the role of Nanotechnology in Imaging and Cancer diagnosis.

Nanotechnology plays a transformative role in imaging and cancer diagnosis by enhancing sensitivity, specificity, and early detection capabilities through nanoscale materials and devices:

1. ***Improved Contrast Agents:*** Nanoparticles like gold nanoparticles, quantum dots, and iron oxide nanoparticles serve as highly effective contrast agents in imaging techniques (MRI, CT, PET, optical imaging). Their unique optical, magnetic, and electronic properties improve image resolution and contrast, helping detect tumors at early stages.
2. ***Targeted Imaging:*** Functionalized nanomaterials can be engineered to selectively bind cancer-specific biomarkers (e.g., receptors or antigens). This targeting allows precise localization of cancer cells, reducing background noise and false positives.
3. ***Multimodal Imaging:*** Nanoparticles can combine several imaging modalities (e.g., MRI + fluorescence) into a single probe, providing complementary information for better diagnosis and monitoring.
4. ***Real-Time Monitoring***: Nanotechnology enables the development of biosensors and nanoscale devices that can detect cancer biomarkers in bodily fluids quickly and non-invasively, facilitating early diagnosis and treatment monitoring.
5. ***Molecular Imaging:*** Nanoprobes allow visualization of molecular and cellular processes associated with cancer progression, aiding in understanding tumor biology and personalized therapy decisions.

25. Write criteria for choosing a sensor.

When choosing a sensor, especially in nanobiotechnology applications, key criteria include:

1. ***Sensitivity:*** Ability to detect low concentrations of the target analyte accurately.
2. ***Selectivity/Specificity:*** Capability to distinguish the target molecule from similar substances or interfering compounds.
3. ***Response Time:*** Speed at which the sensor provides a measurable and stable signal after exposure to the analyte.
4. ***Stability and Reproducibility:*** Consistent performance over multiple uses and under varying environmental conditions.
5. ***Limit of Detection (LOD):*** The smallest amount of analyte that can be reliably detected.
6. ***Range of Detection:*** The concentration range over which the sensor provides accurate measurements.
7. ***Biocompatibility:*** Non-toxic and compatible with biological samples when used in medical or environmental applications.
8. ***Cost and Ease of Fabrication:*** Economic feasibility and simplicity of producing the sensor for widespread use.
9. ***Portability and Size:*** Suitability for on-site or point-of-care applications, often requiring miniaturization.
10. ***Compatibility with Signal Transduction Methods:*** Must effectively integrate with electrical, optical, or other signal detection systems.

26. Write application SAMs.

Self-Assembled Monolayers (SAMs) have versatile applications due to their ability to form well-ordered, functionalized surfaces at the nanoscale:

1. ***Biosensors:*** SAMs provide tailored surfaces for immobilizing biomolecules (antibodies, enzymes, DNA) to enhance sensor sensitivity and specificity.
2. ***Surface Modification:*** Used to control surface properties such as wettability, adhesion, friction, and corrosion resistance in materials science.
3. ***Nanoelectronics:*** Form ultrathin insulating or conductive layers in molecular electronics and device fabrication.
4. ***Catalysis:*** Functionalized SAMs act as catalytic surfaces or supports, improving reaction selectivity and efficiency.
5. ***Biomedical Devices:*** Modify implant surfaces to improve biocompatibility, reduce fouling, and promote cell attachment or inhibit bacterial growth.
6. ***Microfabrication:*** Serve as resist layers or templates for patterning nanostructures in lithography.
7. ***Corrosion Protection:*** SAMs create protective coatings on metals to prevent oxidation and degradation.

27. Write current uses of Nanotechnology in environmental field.

Nanotechnology is increasingly applied in the environmental field to improve monitoring, protection, and remediation efforts:

1. ***Water Treatment:*** Nanomaterials like nanosilver, titanium dioxide nanoparticles, and carbon nanotubes are used for removing contaminants—heavy metals, pathogens, organic pollutants—through adsorption, photocatalysis, and filtration.
2. ***Air Purification:*** Nanofilters and nanocatalysts capture or degrade pollutants, particulate matter, and harmful gases in air filtration systems and industrial emissions control.
3. ***Soil Remediation:*** Nanoparticles can immobilize or degrade toxic substances in contaminated soils, enhancing cleanup efficiency.
4. ***Environmental Sensing:*** Nanosensors detect pollutants, toxins, or pathogens at very low concentrations in water, air, and soil, enabling real-time and on-site monitoring.
5. ***Energy-efficient Catalysis:*** Nanocatalysts promote green chemical reactions and degradation of pollutants using less energy and generating fewer byproducts.
6. ***Renewable Energy:*** Nanotechnology improves the efficiency of solar cells and energy storage devices, supporting sustainable energy solutions that reduce environmental impact.

28. Define Nanoporous, Nanocrystalline and Nanocomposite.

Nanoporous Materials: Materials that contain pores or voids with sizes in the nanometer range (typically 1–100 nm). These pores provide a large surface area and unique properties useful for filtration, catalysis, sensing, and adsorption applications.

Nanocrystalline Materials: Solids composed of grains or crystallites with sizes in the nanometer scale (usually less than 100 nm). These materials exhibit enhanced mechanical, optical, and electrical properties due to their small grain size and high grain boundary area.

Nanocomposites: Hybrid materials made by embedding nanoparticles (such as nanoclays, carbon nanotubes, or metal nanoparticles) into a bulk matrix (polymer, ceramic, or metal). Nanocomposites combine the properties of both components, resulting in improved strength, durability, conductivity, or functionality.

29. Write technique used in Medical Imaging and Pathogen Detection.

Techniques used in Medical Imaging:

1. ***Magnetic Resonance Imaging (MRI) –*** uses magnetic fields and radio waves to produce detailed images of organs and tissues.
2. ***Computed Tomography (CT) Scan –*** employs X-rays to create cross-sectional images of the body.
3. ***Positron Emission Tomography (PET) –*** uses radioactive tracers to visualize metabolic processes.
4. ***Optical Imaging –*** includes fluorescence and bioluminescence imaging often enhanced by nanoparticles.
5. ***Ultrasound Imaging –*** uses high-frequency sound waves to generate images of soft tissues.
6. ***Photoacoustic Imaging –*** combines optical and ultrasound techniques, enhanced by nanomaterials.

Techniques used in Pathogen Detection:

1. ***Biosensors –*** often based on nanomaterials, detecting specific pathogens via electrical, optical, or electrochemical signals.
2. ***Polymerase Chain Reaction (PCR) –*** amplifies pathogen DNA/RNA for identification.
3. ***Enzyme-Linked Immunosorbent Assay (ELISA) –*** detects antigens or antibodies related to pathogens.
4. ***Lateral Flow Assays –*** rapid immunoassays for point-of-care pathogen detection.
5. ***Surface Plasmon Resonance (SPR) –*** monitors pathogen binding in real-time using nanostructured surfaces.
6. ***Nanoparticle-based Colorimetric Assays –*** detect pathogens via color changes mediated by nanoparticles.

30. What are methods of Vaccine Delivery?

1. ***Intramuscular Injection:*** Most common method, delivering vaccines deep into muscle tissue for strong immune response.
2. ***Subcutaneous Injection:*** Vaccine injected under the skin, used for some live attenuated vaccines.
3. ***Oral Delivery:*** Vaccine taken by mouth, like the polio vaccine, convenient and needle-free.
4. ***Nasal Spray:*** Administered through the nose to stimulate mucosal immunity (e.g., influenza nasal vaccine).
5. ***Transdermal Delivery:*** Using microneedles or patches to deliver vaccine through the skin painlessly.
6. ***Nanoparticle-based Delivery:*** Encapsulating vaccines in nanoparticles for targeted delivery, controlled release, and enhanced immune response.
7. ***Intradermal Injection:*** Injection into the skin layer, which is rich in immune cells, allowing dose sparing.

31. What are responsive Nano coatings?

Responsive nano coatings are smart thin films engineered at the nanoscale that can change their physical or chemical properties in response to external stimuli such as temperature, pH, light, humidity, magnetic or electric fields. These coatings adapt dynamically to their environment, providing active functions rather than just passive protection. Key features of responsive nano coatings include:

- ***Stimuli-Responsive Behavior:*** They undergo reversible changes like swelling, color change, conductivity variation, or surface wettability alteration upon stimulus exposure.
- ***Self-Healing:*** Some can repair minor damages automatically when triggered by environmental cues.
- ***Controlled Release:*** Enable timed or triggered release of drugs, antimicrobials, or corrosion inhibitors.
- ***Adaptive Protection:*** Change surface properties to prevent fouling, corrosion, or bacterial adhesion based on environmental conditions.

Applications include:

- Anti-fouling and anti-corrosion surfaces
- Drug delivery systems with on-demand release
- Sensors and actuators
- Smart textiles and biomedical implants

32. What is Spectroscopy and X-Ray? Give details.

Spectroscopy is a broad analytical technique that studies the interaction between electromagnetic radiation and matter to identify and characterize substances. It measures how materials absorb, emit, or scatter light (or other electromagnetic waves) across different wavelengths, providing information about molecular structure, composition, and dynamics.

- ***Types of Spectroscopy:*** Includes UV-Vis, Infrared (IR), Nuclear Magnetic Resonance (NMR), Fluorescence, Raman, and Mass Spectrometry.
- ***Applications:*** Used in chemical analysis, material characterization, biological studies, and monitoring molecular interactions.

X-Ray refers to high-energy electromagnetic radiation with wavelengths shorter than visible light, typically used in imaging and structural analysis.

- ***X-Ray Imaging:*** Utilizes X-rays to penetrate tissues and create images based on differential absorption, widely used in medical diagnostics (X-ray radiography, CT scans).
- ***X-Ray Crystallography:*** Analyzes the diffraction patterns of X-rays passing through crystalline materials to determine atomic and molecular structures.
- ***X-Ray Spectroscopy:*** Techniques like X-ray fluorescence (XRF) and X-ray photoelectron spectroscopy (XPS) analyze elemental composition and chemical states.

33. Differentiate between superhydrophobic and superhydrophilic coating.

Superhydrophobic coatings are surfaces designed to repel water, characterized by water contact angles greater than 150°. On these coatings, water droplets bead up and roll off easily, carrying away dirt and contaminants, which provides self-cleaning and waterproofing effects. This behavior results from very low surface energy combined with micro- and nanoscale surface roughness. They are widely used in applications like waterproof textiles, anti-fouling surfaces, and corrosion protection.

Superhydrophilic coatings have water contact angles less than 10°, causing water to spread out evenly and form a thin film rather than droplets. These surfaces have very high surface energy, which promotes strong water affinity and absorption. Superhydrophilic coatings are useful for anti-fogging treatments, enhancing adhesion in biomedical devices, and improving wettability in various applications. While superhydrophobic coatings prevent water adhesion, superhydrophilic coatings encourage it, making each type suitable for different technological and environmental needs.

34. How Nucleic Acid interacts to bio recepotors?

Nucleic acids interact with bio receptors primarily through specific molecular recognition based on complementary base pairing. Single-stranded DNA or RNA probes on the bio receptor surface bind selectively to their complementary target nucleic acid sequences through hydrogen bonding between the nucleotide bases (A-T/U and G-C). This hybridization event forms a stable double-stranded structure, enabling precise detection of genetic material. Additionally, bio receptors can be designed to recognize specific nucleic acid conformations or modifications. The binding often triggers a measurable signal—such as an electrical, optical, or electrochemical change—that biosensors can detect in real time. This highly selective interaction forms the basis of many diagnostic tools for detecting pathogens, genetic mutations, and gene expression levels.

35. Write functions of Biometric membrane sheet.

Functions of biometric membrane sheets include:

1. ***Selective Permeability:*** They allow selective transport of molecules such as nutrients, gases, and signaling molecules while blocking unwanted substances, maintaining controlled exchange between compartments.
2. ***Protection:*** Act as protective barriers to cells or tissues from physical damage, pathogens, and toxins.
3. ***Support for Cell Growth:*** Provide a scaffold or support for cell attachment, proliferation, and differentiation in tissue engineering.
4. ***Separation and Filtration:*** Used in separation processes to filter biomolecules based on size, charge, or affinity.
5. ***Facilitate Communication:*** Enable communication between cells or between biological systems by controlling the passage of signaling molecules.
6. ***Biocompatibility:*** Offer compatibility with biological systems, minimizing immune responses or rejection when used in implants or devices.

Disclaimer:

For best results, it is advised NOT to rely on this file only. Go through video lectures, handouts and other sources as well.

Regards,
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