

Fundamentals of Protein Chemistry
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Module - 11
Protein Macromolecule Interactions II
Lecture - 55
Protein Nanoparticle Interactions

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CONCEPTS COVERED

- Nanoparticles and the protein corona
- Impact of protein-NP interactions on biological processes
- Methods to detect protein nanoparticle interactions
- Applications of protein-NP interactions



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In our final discussion on protein macromolecular interactions, we will be looking at protein nanoparticle interactions. These are important interactions because they deal with a protein interaction in the term of a protein corona. We will look at the impact of protein nanoparticle interactions on biological processes, methods to detect them and how they are applied in nano medicine.

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KEYWORDS

- Surface plasmon resonance
- Nano-bio interface
- Bioimaging, sensing
- Cytotoxicity
- Hard and Soft corona






When we look at these specific terminologies, we will be looking at what we mean by surface plasmon resonance, the nano-bio interface, bioimaging, cytotoxicity, the hard and soft corona.

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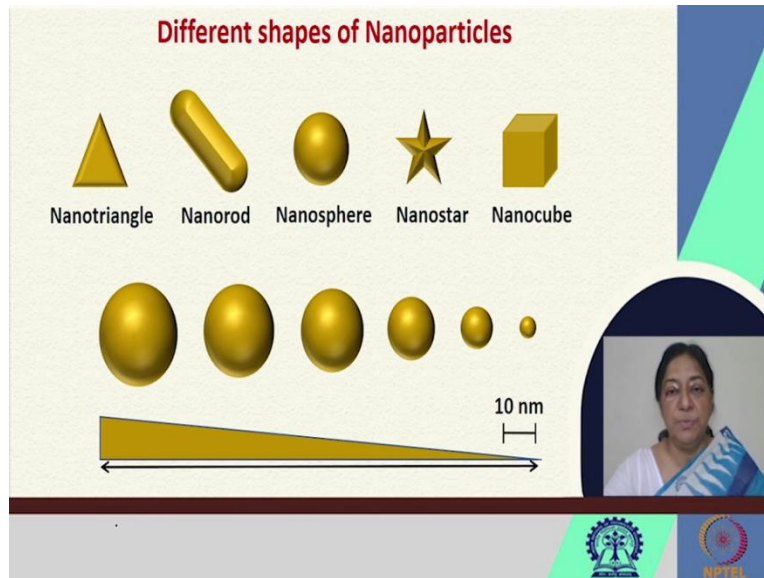
Nanoparticles

- Particles that range between 1 and 100 nm in size at least in one dimension.
- They exhibit different optical, physical and chemical properties compared to their larger material counterparts.
- These properties are highly dependent on the size as well as the shape or morphology of the nanoparticles.



When we try and understand what nanoparticles are, these are particles that range between 1 and 100 nm in size at least in one dimension. They exhibit different optical, physical and chemical properties, compared to the larger material bulk counterpart. These properties are highly dependent on the size as well as the shape or the morphology of the nanoparticles.

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So if we look at the different shapes of nanoparticles that are possible, we could have nano triangles, rods, spheres, stars, even flowers, nano cubes and so on and so forth and depending upon the shapes and the sizes, they have different properties that can be exploited in various ways.

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Metallic NPs have gain huge popularity for several applications in diagnostics and therapeutics

- ❖ Physiochemical properties
- ❖ high stability
- ❖ high reactivity
- ❖ photothermal and plasmonic properties

Can be used as high sensitivity labels in immune sensors/immunoassays, bio-imaging, gene diagnostics, photothermal treatment of tumors and targeted delivery of various biomolecules.

Metallic nanoparticles have gained a huge popularity for several applications in diagnostics and therapeutics, where the concept of a protein nanoparticle interaction or an understanding is important. The properties that are exploited are the physiochemical properties that has high stability, high reactivity and photothermal and plasmonic properties.

Thus, they can be used as high sensitivity labels in immune sensors or immunoassays, bio imaging, gene diagnostics, photothermal treatment of tumors and targeted delivery of various biomolecules and drugs.

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These nanoparticles show localized surface plasmon resonance (LSPR), which is the collective oscillations of free electrons at a metal dielectric interface when the frequency of incident light matches with the frequency of electron oscillation.

Metal nanoparticles e.g. gold and silver, have been intensively researched for use in biomedicine and more specifically for the development of highly sensitive inexpensive detection assays

The slide features a yellow background with a blue and green geometric design on the right. It includes two spheres, one gold and one silver, representing nanoparticles. A small inset photo of a woman is visible in the bottom right corner. Logos for IIT Bombay and NPTEL are at the bottom.

When we look at the nanoparticles, what they do is they show localized surface plasmon resonance, which is the collective oscillations of the free electrons at a metal dielectric interface, when the frequency of the incident light matches with the frequency of the electron oscillation thus being a resonance.

The metal nanoparticles for example, gold and silver have been intensively researched for use in biomedicine and more specifically for the development of high sensitive inexpensive detection assays.

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Colloidal gold nanoparticles have been intensively explored for the purpose of biosensing due to their optical and physical properties.

❖ Gold nanoparticles can be synthesized in a wide range of sizes and shapes 

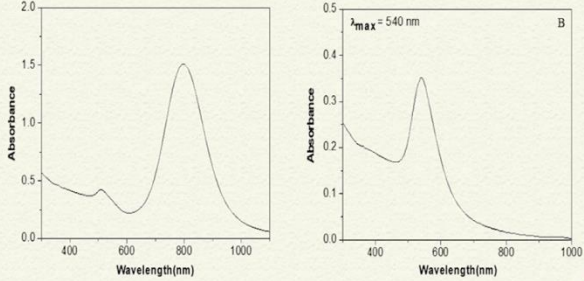
❖ They absorb light very strongly and the absorption maxima can be tuned from the visible to the near infrared (a region where tissue absorbs weakly and is therefore useful for biomedical applications)








The colloidal gold nanoparticles have been intensively explored for the purpose of biosensing, due to their optical and physical properties. So the gold nanoparticles as we saw, can be synthesized in various sizes and shapes. They absorb light very strongly and the absorption maxima, can be tuned from the visible to the near infrared. This is the region where the tissue absorbs weakly and thus they can be used for biomedical applications.

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UV-Vis absorption spectra for Gold Nanoparticles, Absorption maxima ranges between 450 nm to 800 nm (visible-NIR).

This [refer to slide] is a typical spectra for the UV-Vis absorption spectra for gold nanoparticles, where the absorption maxima ranges between 450 and 800 nm.

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Gold Nanoparticles

Exciting plasmonic properties

Gold nanorods UV-Vis spectral shift

AR: 2.4 5.7

AR: 2.4 2.6 2.8 3.6 4.6 5.2 5.7 6.8

Extinction (a.u.)

Wavelength (nm)

NPTEL

There are exciting plasmonic properties of these gold nanoparticles and what happens for these gold nano rods, there is a spectral associated with the size and the shape of the nanoparticle.

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Gold Nanoparticles

Biocompatibility

Several studies show that the AuNPs are biocompatible materials *in vitro* and *in vivo* at low concentrations.

NPTEL

Their bio compatibility is also extremely important and several studies with gold nanoparticles, show that they are biocompatible *in vitro* and *in vivo* at low concentrations.

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Gold Nanoparticles

Facile surface modification

AuNPs can easily be modified with different molecules for biomedical applications.

The other advantage of gold nanoparticles is, it is possible for surface functionalization or surface modification. This surface modification as we can see [refer to slide] in the figure, can be accomplished by many other smaller biomolecules that can be used for various properties. So whether we are attaching a protein, an antibody, a cell penetrating peptide, a dendrimer, a fluorescent molecule, siRNA, PEG, single stranded DNA, an aptamer or a drug, would depend upon the specific application that we would be interested in.

So, these gold nanoparticles can easily be modified with different molecules for several biomedical applications.

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Nano-bio interface

Suspending medium

Nanoparticle

Solid-liquid interface

Nano-bio interface

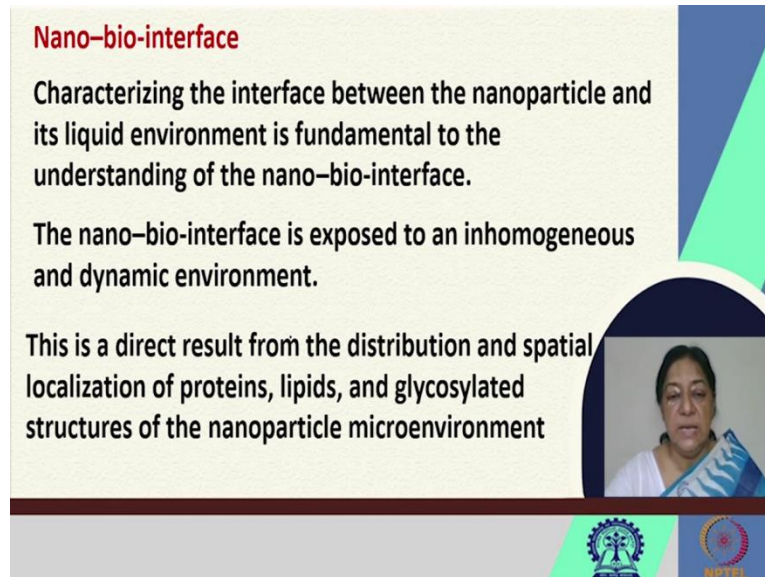
Lipid bilayer

Proteins

The nano-bio interface is an important aspect because we consider their attachment to the cell or their interaction with body fluids. We have a solid liquid interface and there are the special

properties of the lipid bilayer where we have the embedded proteins, where there could be specific interactions depending upon the type of process that is being looked at.

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Nano-bio-interface

Characterizing the interface between the nanoparticle and its liquid environment is fundamental to the understanding of the nano-bio-interface.

The nano-bio-interface is exposed to an inhomogeneous and dynamic environment.

This is a direct result from the distribution and spatial localization of proteins, lipids, and glycosylated structures of the nanoparticle microenvironment

The slide features a video inset of a woman speaking, set against a background with blue and green geometric shapes. At the bottom, there are logos for IIT Bombay and NPTEL.

So characterizing this nano-bio interface between the nanoparticle and its liquid environment, is fundamental to the understanding of this specific interface. This is because it is exposed to an inhomogeneous and dynamic environment, given that it is interacting with the cellular environment; the extracellular and intracellular environment, if it is allowed to pass the cell membrane.

This is a direct result from the distribution and spatial localization of the proteins, the lipids and glycosylated structures of the nanoparticle micro environment and each of these are going to have a specific feature or a specific characteristic that is going to affect the overall property of the nanoparticle.

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Nano-bio interface

To study the safe use of nanomaterials it is essential to examine:

- the dynamic physicochemical interactions
- the kinetics
- thermodynamics of the interaction between the surfaces of the nanomaterial and the biological components

Examples of such components are proteins, membranes, phospholipids, endocytic vesicles, organelles, DNA, and biological fluids

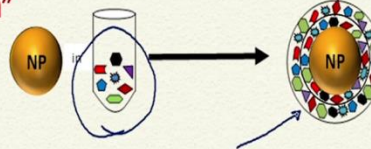


To study the safe use of nanomaterials, it is essential to examine the dynamic physiochemical interactions, the specific kinetics and the thermodynamics of the interactions between the surfaces of the nanomaterial and the biological components. Examples of the components that the interaction can occur with are proteins, membranes, phospholipids, endocytic vesicles, several organelles DNA and biological fluids.

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Protein corona

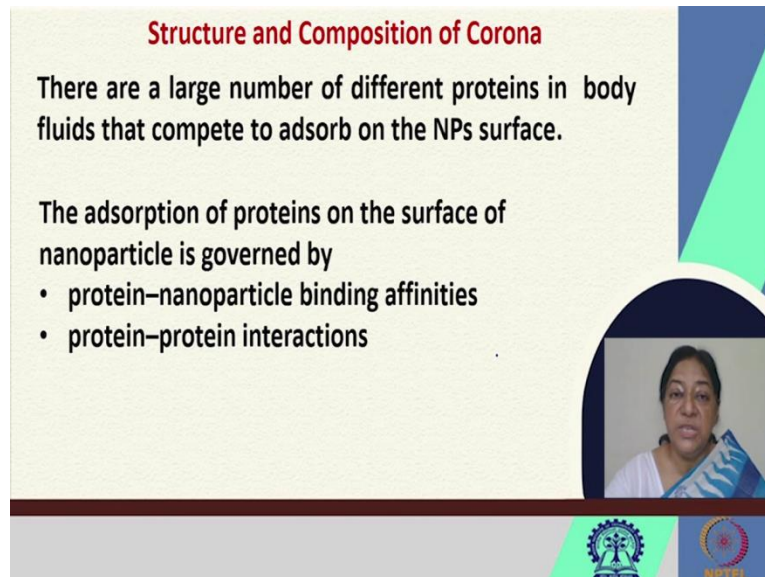
When NPs enter into the biological fluid then various biological molecules specially proteins are instantaneously adsorbed onto the NPs surface, giving the new biological identity to the nanoparticles, termed as "protein corona"



In this case we will be looking at the interaction with proteins in the formation of what is called a protein corona. When nanoparticles enter into the biological fluid, then there are various molecules particularly proteins, that are instantaneously adsorbed onto the nanoparticle surface. The interaction with biofluids, on their first interaction when a nanoparticle enters a biological fluid, these proteins adsorb on the surface of the nanoparticle and this is termed as the protein corona.

So we have a protein corona that has the nanoparticle, several proteins that can interact with the nanoparticles. If we have a mixture of proteins they can interact with the nanoparticles and their interaction would depend upon the properties of the proteins, their charge and their specific characteristics, depending upon the surface interactions that are going to interact with the nanoparticles.

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Structure and Composition of Corona

There are a large number of different proteins in body fluids that compete to adsorb on the NPs surface.

The adsorption of proteins on the surface of nanoparticle is governed by

- protein–nanoparticle binding affinities
- protein–protein interactions

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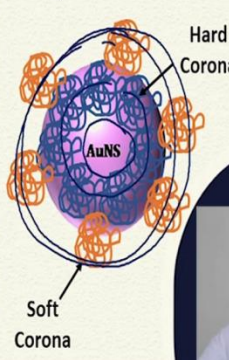
The structure and the composition of the corona based on the proteins involved in this case, there are a large number of different proteins in the body fluids that can compete to adsorb on the nanoparticle surface. In this case the affinity with the nanoparticle is going to be important. So, the absorption of the proteins on the surface of the nanoparticle is governed by the protein nanoparticle binding affinities and protein-protein interactions.

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Structure and Composition of Corona

Proteins that adsorb with high affinity form what is known as the “hard” corona, consisting of tightly bound proteins that do not readily desorb

Proteins that adsorb with low affinity form the “soft” corona, consisting of loosely bound proteins



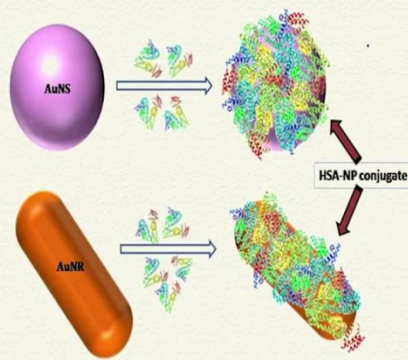
The diagram shows a central purple sphere labeled 'AuNS'. It is surrounded by two layers of orange protein structures. The inner layer is labeled 'Hard Corona' and the outer layer is labeled 'Soft Corona'. A small inset video of a woman is visible in the bottom right corner of the slide.

The proteins that adsorb with high affinity from what is called the hard corona, consisting of tightly bound proteins that do not readily desorb from the surface and the proteins that adsorb with low affinity, from what is called the soft corona that consists of loosely bound proteins. We have a hard corona if we look at a gold nanosphere, where we have the proteins that are tightly bound to the surface because of their high affinity.

We have a soft corona that is loosely bound, where there is an exchange with the fluid and with the surface of the soft corona, whereas the hard corona proteins are tightly bound.

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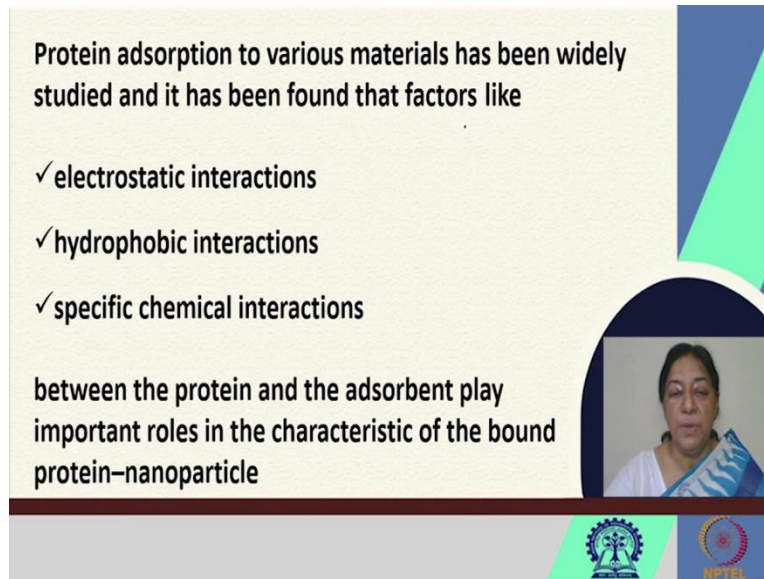
Protein corona on Gold Nanoparticles



The diagram shows two pathways. The top pathway starts with a purple spherical nanoparticle labeled 'AuNS' and several green protein structures. An arrow points to a spherical nanoparticle completely covered in a multi-colored protein corona. The bottom pathway starts with an orange rod-shaped nanoparticle labeled 'AuNR' and several green protein structures. An arrow points to a rod-shaped nanoparticle covered in a multi-colored protein corona. A red arrow labeled 'HSA-NP conjugate' points from both resulting coronas to a central point.

If we look at the protein corona on the gold nanoparticles, depending upon the shape, the protein nanoparticle conjugate can have different notations, different ways in which they could interact and different ways in which the affinity for the gold nanoparticle may be affected.

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Protein adsorption to various materials has been widely studied and it has been found that factors like

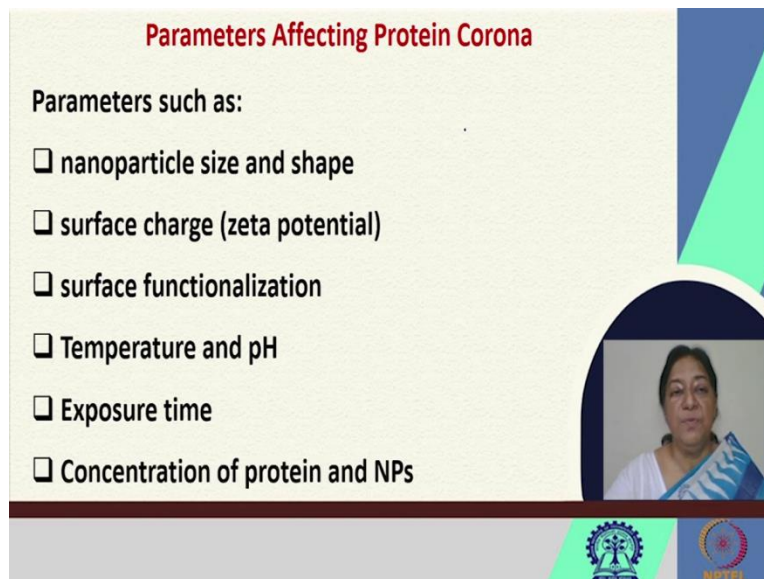
- ✓ electrostatic interactions
- ✓ hydrophobic interactions
- ✓ specific chemical interactions

between the protein and the adsorbent play important roles in the characteristic of the bound protein–nanoparticle

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The protein adsorption on the materials has been widely studied and it has been found that factors like the electrostatic interactions, the hydrophobic interactions, the specific chemical interactions are important between the protein and the adsorbent, that play important roles in the characteristic of the bound protein nanoparticle.

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Parameters Affecting Protein Corona

Parameters such as:

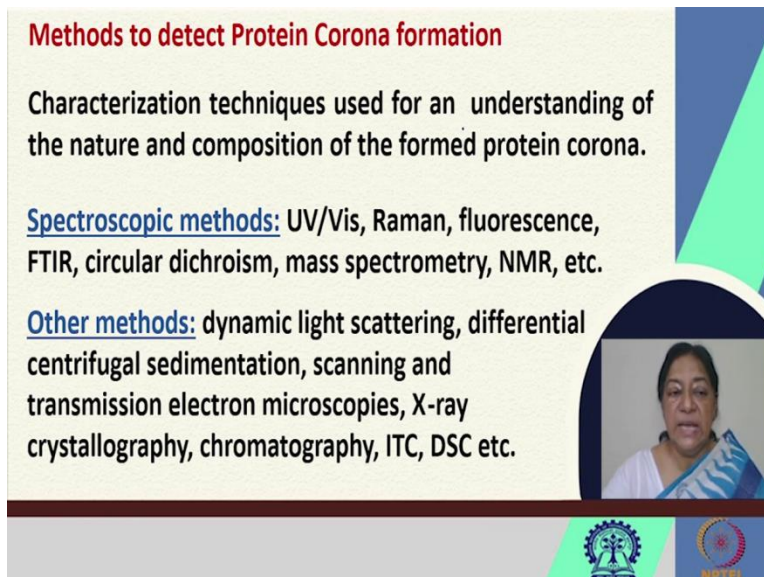
- nanoparticle size and shape
- surface charge (zeta potential)
- surface functionalization
- Temperature and pH
- Exposure time
- Concentration of protein and NPs

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The parameters that can affect this protein corona are the nanoparticle size and shape; the surface charge; the surface functionalization; the temperature and the pH because that in turn will affect the structure of the protein and also the charge on the protein would be affected by changes in pH; then the exposure time meaning how long the protein has been allowed to interact with the specific nanoparticle and of course, the concentration of the protein and the nanoparticles.

All of these factors are going to affect the adsorption of the formation of the protein corona that is the proteins on the nanoparticle surface.

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Methods to detect Protein Corona formation

Characterization techniques used for an understanding of the nature and composition of the formed protein corona.

Spectroscopic methods: UV/Vis, Raman, fluorescence, FTIR, circular dichroism, mass spectrometry, NMR, etc.

Other methods: dynamic light scattering, differential centrifugal sedimentation, scanning and transmission electron microscopies, X-ray crystallography, chromatography, ITC, DSC etc.

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If we want to find methods that are going to detect the protein corona formation to understand whether the protein has interacted with the specific nanoparticle, then there are specific characterization techniques that are used for an understanding of the nature and composition of the formed protein corona.

Spectroscopic methods such as UV visible, Raman, fluorescence, FTIR, CD that is circular dichroism, mass spectrometry, NMR. These techniques can be used in addition to optical methods or other methods that could be dynamic light scattering, differential centrifugal sedimentation depending upon the size, then scanning and transmission electron microscopy, X-ray crystallography, chromatography, ITC and DSC.




So, all of these are going to look at the presence of the protein on the nanoparticle and specific interactions that may be possible, the property that may be affected of the nanoparticle and of the protein, due to the interaction that has occurred.

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Amino acid residue interaction with NPs

Nanoparticles interact with different proteins through electrostatic interactions with specific amino acid residues according to the surface charge on the NPs and protein conformation.

Gold nanoparticles interact with serum proteins which consist of amino acids containing thiol groups such as cysteine via noncovalent interactions as well as covalent bond formation with the Au surface to a certain extent.






The amino acid residue interactions with the nanoparticles, they interact with different proteins through electrostatic interactions with specific amino acid residues, according to the surface charge on the nanoparticle as well as the protein. Gold nanoparticles are known to interact with serum proteins which consists of amino acids, that contain thiol groups such as cysteine via non-covalent interactions as well as covalent bond formation, with the gold surface to some extent.

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Interaction of specific residues in serum albumins with gold nanoparticles.

Surface enhanced Raman scattering (SERS) signals indicate:

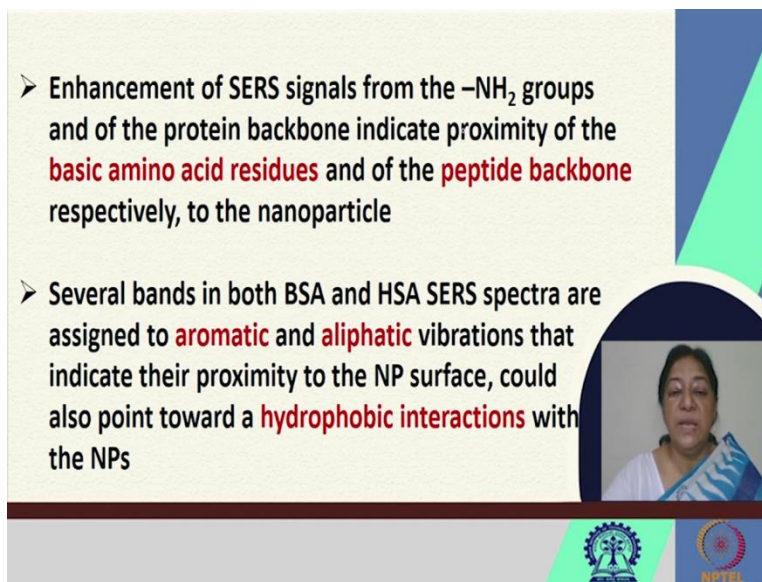
- an electrostatic interaction of proteins with the citrate ligands at the nanoparticle surface *via Lys residues*.
- that the HSA molecules maintain their disulfide bridges as important elements of their secondary structure upon interaction with the NP surface.



So the interaction of specific residues in the serum albumins with the gold nanoparticles, give us surface enhanced Raman scattering signals. These indicate an electrostatic interaction of the proteins with the citrate ligands at the nanoparticle surface via lysine residues, also that the HSL molecules maintain their disulfide bridges as important elements of their secondary structure, upon interaction with the nanoparticle surface.



The interaction that we can see occurs through the gold may occur through a thiol, may also occur through specific electrostatic interactions, depending upon the size and the charge of the specific protein and the nanoparticle of interest.

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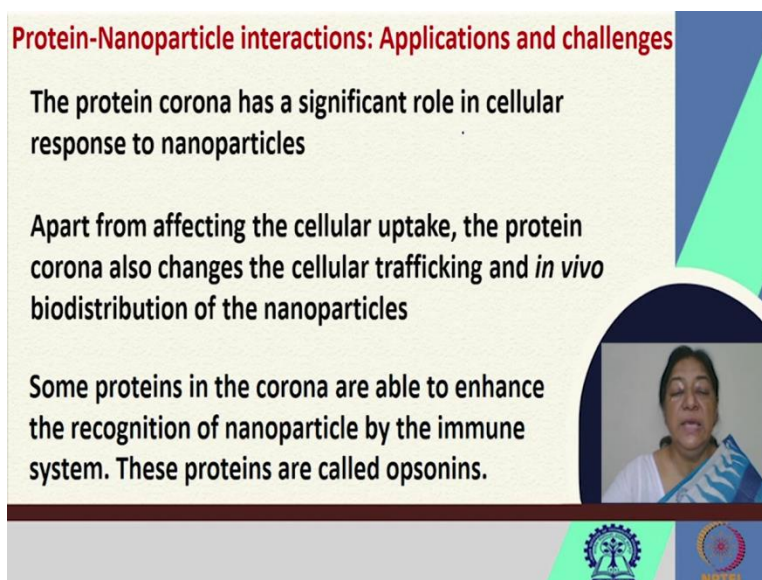
➤ Enhancement of SERS signals from the $-NH_2$ groups and of the protein backbone indicate proximity of the **basic amino acid residues** and of the **peptide backbone** respectively, to the nanoparticle

➤ Several bands in both BSA and HSA SERS spectra are assigned to **aromatic** and **aliphatic** vibrations that indicate their proximity to the NP surface, could also point toward a **hydrophobic interactions** with the NPs



If we look at the enhancement of the SERS signals from the $-NH_2$ groups and of the protein backbone, these indicate proximity of basic amino acids and of the peptide backbone to the nanoparticle. There are several bands in both BSA and HSA, that is bovine serum albumin and human serum albumin spectra, that can also be assigned to aromatic and aliphatic vibrations that indicate their proximity to the nanoparticle surface, that could also point toward a hydrophobic interaction with the specific nanoparticles.

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Protein-Nanoparticle interactions: Applications and challenges

The protein corona has a significant role in cellular response to nanoparticles

Apart from affecting the cellular uptake, the protein corona also changes the cellular trafficking and *in vivo* biodistribution of the nanoparticles

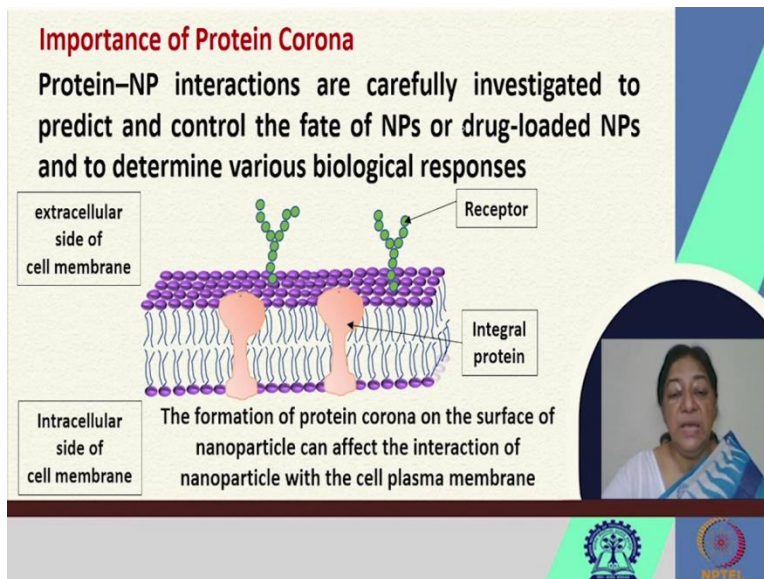
Some proteins in the corona are able to enhance the recognition of nanoparticle by the immune system. These proteins are called opsonins.



If we look at this protein nanoparticle interactions and the specific applications and challenges that come by, the protein corona has a significant role in cellular response to nanoparticles. Apart from affecting the cellular uptake, the protein corona also changes the cellular trafficking and in vivo biodistribution of the nanoparticles, which is dependent on the interactions.

So, some proteins in the corona are able to enhance the recognition of nanoparticles by the immune system. These specific proteins are called opsonins.

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We can look at the importance of the protein corona in terms of the protein nanoparticle interactions, that can be carefully investigated to predict and control the fate of the nanoparticles or drug loaded nanoparticles and to determine various biological responses. So, we look at the interactions with the lipid bilayer. We have the integral protein, we have a specific receptor on the surface, the extracellular side of the cell membrane and the intracellular side of the cell membrane.

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Biological Response to Nanomaterials

Effect of PC on Biological responses

Cytotoxicity

AuNPs Size

Cell-association

Cellular uptake

Biodistribution

Bioavailability

Understanding protein-nanoparticles interactions is essential to stabilize and deliver protein-based therapeutic drugs and vaccines and thus increase the efficacy in biomedical applications.

Now the formation of the protein corona on the surface of the nanoparticle can definitely affect the interaction of the nanoparticle with the cell plasma membrane, depending upon the protein that is present in the membrane or depending on the specific receptors of the surface, on the extracellular side of the cell membrane.

If we look at the specific biological responses to nanomaterials, the effect of a protein corona on these biological responses can result in cytotoxicity, biodistribution changes, bioavailability, cellular uptake, cell association and the variation due to the nanoparticle size. So understanding these protein nanoparticle interactions is essential, to stabilize and deliver protein based therapeutic drugs and vaccines and thus increase the efficacy in biomedical applications.

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Toxicity:
The development of *in vitro* protocols to assess the potential toxicity of the NPs poses a challenge because of the rapid changes of the intrinsic physicochemical properties that occur upon dispersion in biological fluids.

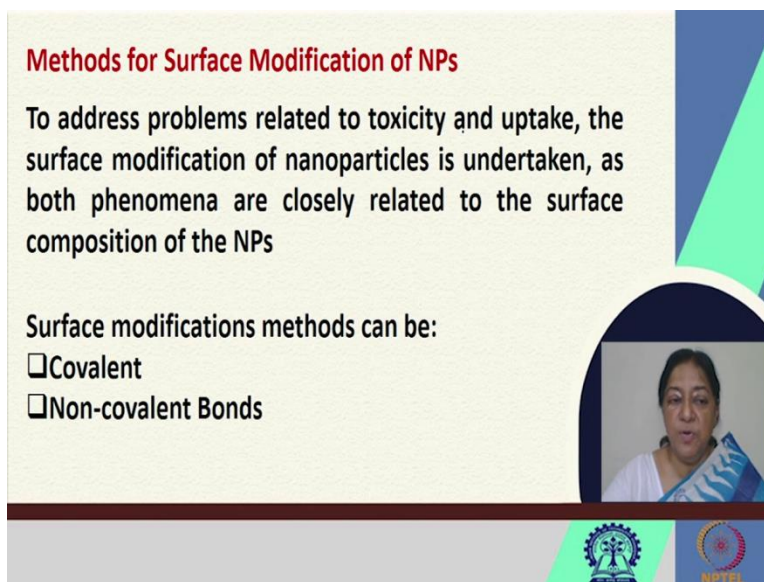
Rapid Clearance:
PC can encourage the phagocytosis and rapid clearance of NPs from blood circulation.

Further detailed studies required to investigate the protein corona to elicit optimum properties.

The development of in vitro protocols to assess the potential toxicity of the nanoparticles, poses a challenge because of the rapid changes in the intrinsic physiochemical properties that can occur upon dispersion in biological fluids because we have to understand that the content or the extent of the biological fluids is a dynamic process and is constantly changing.

So, there are going to be constant variations and this could give specific differences to the toxicity that is observed. A rapid clearance is also necessary where the protein corona can encourage phagocytosis and rapid clearance of the nanoparticles from blood circulation and so further detailed studies are required to investigate the protein corona to elicit optimum properties.

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Methods for Surface Modification of NPs

To address problems related to toxicity and uptake, the surface modification of nanoparticles is undertaken, as both phenomena are closely related to the surface composition of the NPs

Surface modifications methods can be:

- Covalent
- Non-covalent Bonds

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There are methods for surface modification of nanoparticles, so that they can be optimally utilized and to address problems related to the toxicity and the uptake, surface modification of nanoparticles is undertaken, as both phenomena are closely related to the surface composition of the nanoparticles. The surface modifications can be either covalent bond formation or non covalent interactions.

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Methods for Surface Modification of NPs

The surface functionalization of NPs involves a process that aims to improve and/or add properties useful for the use of NPs in medical applications.

The first phase of the surface modification is based on the use of cross linkers to add a functional group (R-NH₂, R-COOH, etc.) that can be exploited to bind biological molecules.






The methods for surface modification include surface functionalization, involving a process that aims to improve and/or add properties useful for the use of nanoparticles in medical applications. The first phase of the surface modification is based on the use of cross linkers. These add specific functional groups to the surface that can be exploited, to further bind biological molecules.

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Methods for Surface Modification of NPs

- ❑ For silica NPs, the most used linkers are **aminosilanes** that introduce an amino group on the NP surface for bio-conjugation.
- ❑ Noble metals, like gold, can be functionalized by using crosslinkers with **-SH** or **-NH₂** groups able to react with the metal and to produce a covalent bond.

These bi-functional linkers, such as thio-carboxylic acids, have at the other end functional groups to use for binding ligands



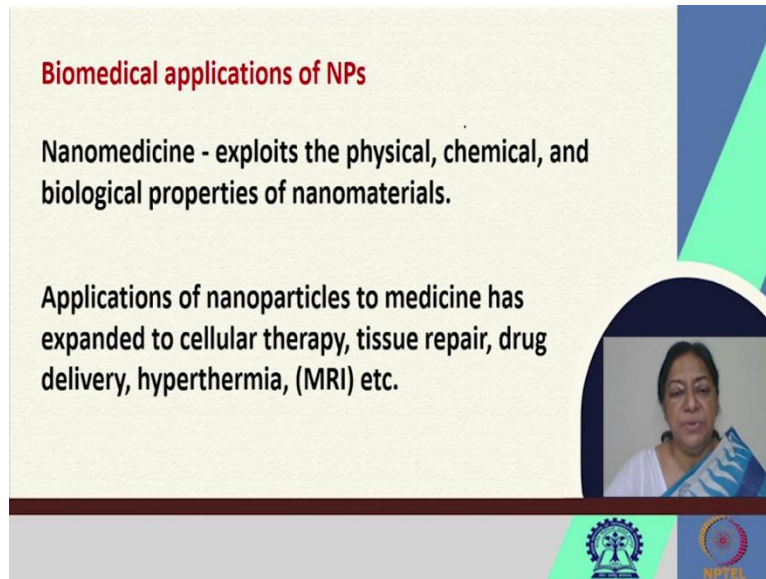
For example in silicon nanoparticles the most used linkers are aminosilanes, that introduce an amino group on the nanoparticle surface for possible bio-conjugation. Similarly for noble metals like gold, they can be functionalized by using cross linkers with -SH or -NH₂ groups attached to them, that can react to produce a covalent bond. So, such bifunctional linkers such as the thio-carboxylic acids, have at the other end functional groups that can be used for binding specific ligands.

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Biomedical applications of NPs

Nanomedicine - exploits the physical, chemical, and biological properties of nanomaterials.

Applications of nanoparticles to medicine has expanded to cellular therapy, tissue repair, drug delivery, hyperthermia, (MRI) etc.

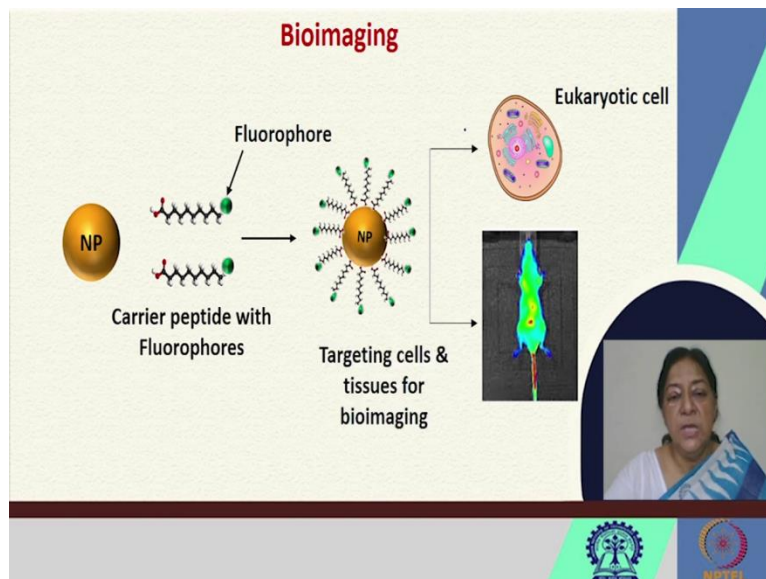


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The biomedical applications of nanoparticles are very diverse. In nanomedicine, this exploits the physical, chemical and biological properties of the nanomaterials. So the applications of nanoparticles to medicine has expanded from cellular therapy, to tissue repair, to drug delivery, MRI, hyperthermia and many other methodologies.

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Bioimaging



The diagram shows a gold nanoparticle (NP) and a carrier peptide with fluorophores. The carrier peptide binds to the NP, forming a complex. This complex targets cells and tissues for bioimaging. The process results in a eukaryotic cell and a bioimaging image of a mouse.


Fluorophore

Carrier peptide with Fluorophores

NP

Targeting cells & tissues for bioimaging

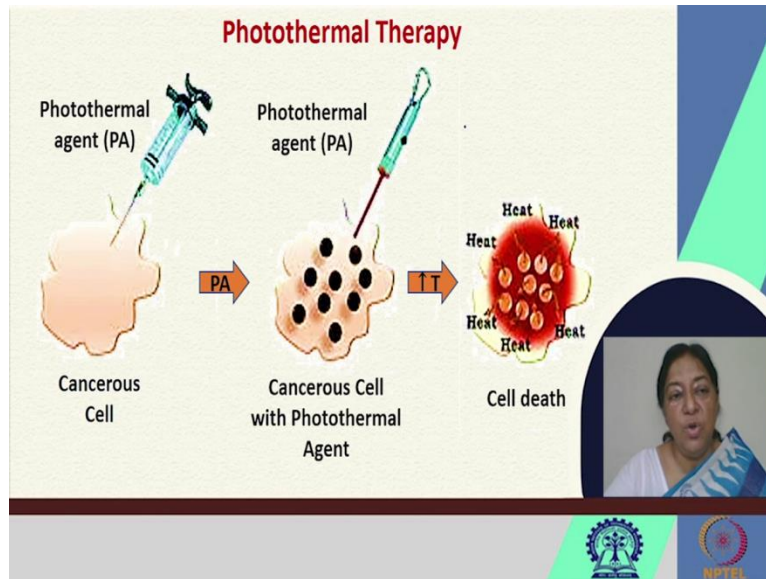
Eukaryotic cell



The slide has a light green background with a blue and green geometric design on the right. It contains a diagram of the bioimaging process and a video inset of a woman speaking. Logos for a university and NPTEL are at the bottom.

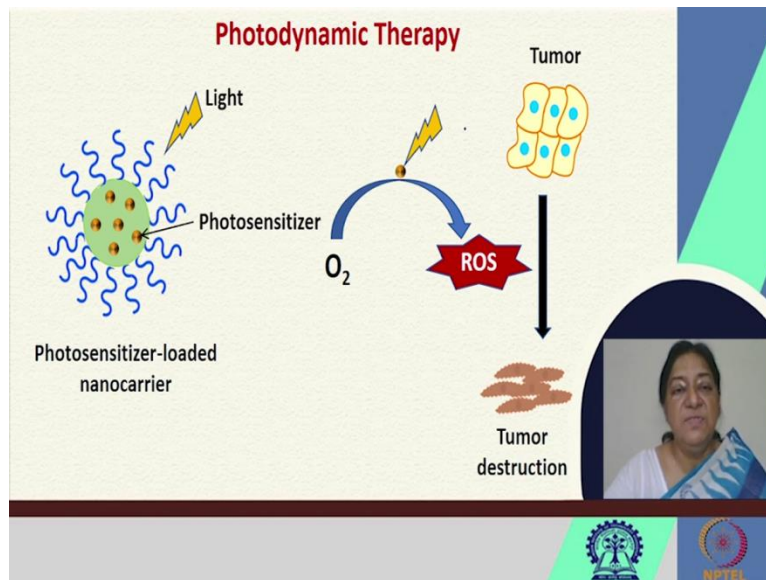
These can be summarized in the following slides [refer to the slides] where they can be used in bioimaging techniques, where the nanoparticle has a fluorophore and a carrier peptide with the fluorophore, that is then bound to the nanoparticle and then trapped in the eukaryotic cell in a bioimaging process, looking at targeting cells and tissues for bioimaging.

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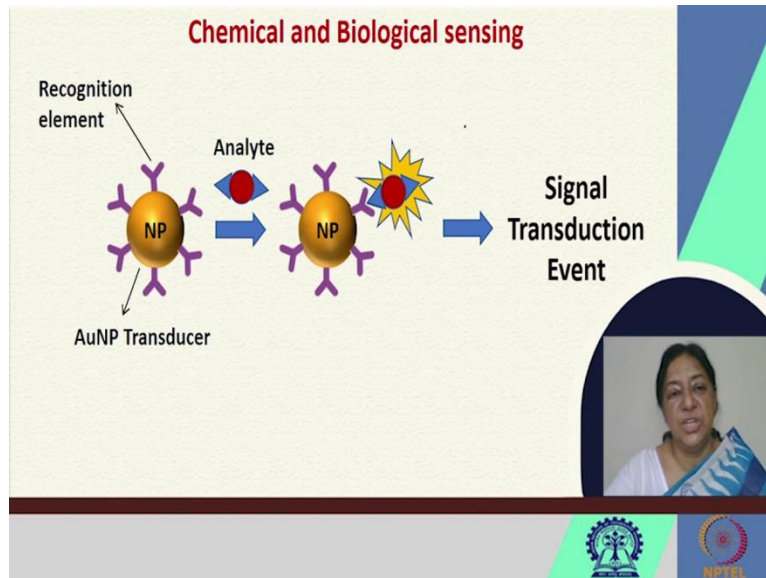
In photothermal therapy as the name implies, if there is a cancerous cell, a photothermal agent then can be targeted with a nanoparticle and a photothermal agent created and the cancerous cell, with the photothermal agent then get destructed with the application of heat.

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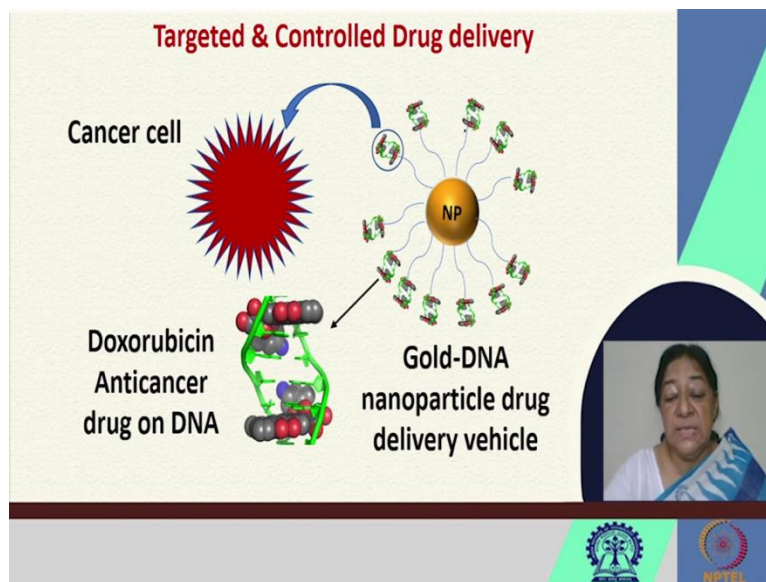
In a photodynamic therapy, we have photosensitizers loaded nanocarriers. In this [refer to slide] case there is a photosensitizer and specific light is going to then create specific reactive oxygen species, ROS and result in tumor destruction.

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In chemical and biological sensing, we have the nanoparticles that have specific transducers attached to them, a recognition element such as an antibody that can attach specific molecules to it and can be used for biological sensing. So, this could generate a signal that then can be studied with a signal transduction event.

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Targeted and controlled drug delivery is what is extremely important. So in this [refer to slide] case for example, doxorubicin anticancer drug on DNA and a cancer cell, the gold DNA nanoparticle drug delivery vehicle was able to deliver doxorubicin. But again this is extremely important in where it is going and how it is being delivered and of course, the clearance of the nanoparticle as well.




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Peptides as modifying agents

The covalent binding of molecules on the NPs surface is widely used to bind antibodies, aptamers and **peptides** exploited to enhance uptake and to perform active targeting.

A widely explored strategy to increase NPs uptake is based on the use of **cell penetrating peptides (CPPs)**.

These molecules are composed of a specific amino acid sequence, usually polycationic or amphipathic structures, that enhance NP uptake.



Here peptides can be used as modifying agents. The covalent binding of molecules on the nanoparticle surface is widely used to bind antibodies, aptamers and peptides, that are exploited to enhance uptake and to perform active targeting. A widely used explore strategy to do this, is using cell penetrating peptides, the topic that we discussed in protein peptide interactions. So, these molecules are composed of specific amino acid sequences that can enhance nanoparticle uptake.




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Protein-Based Nanoparticles as Drug delivery systems

Research related to Drug delivery systems and targeted Drug delivery are becoming increasingly important.

Various nanomaterials are used but protein NPs offer several advantages.

Important advantage of protein nanoparticles
e.g. biocompatibility and biodegradability



The protein-based nanoparticles are thus used as drug delivery systems. The research related to drug delivery systems and targeted drug delivery are becoming increasingly important. Various nanoparticles have been used, but protein nanoparticles offer several advantages. First, the important advantage of the use of protein nanoparticles, is their biocompatibility and their biodegradability.

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Protein-Based Nanoparticles as Drug delivery systems

- ❑ The preparation of protein nanoparticles and the corresponding encapsulation process involve mild conditions with no toxic chemicals/ organic solvents.
- ❑ The stability, activity, and half-life can be improved by protecting the drug from enzymatic degradation.
- ❑ Protein nanoparticles can be used in a variety of targeted therapies including cancer therapy.

The slide features a video inset of a woman in the bottom right corner and logos for IIT Bombay and NPTEL at the bottom.

The preparation of protein nanoparticles and the corresponding encapsulation process of drugs or specific compounds, involve relatively mild conditions with no toxic chemicals or organic solvents that are primarily used. The stability, activity and half-life, can be improved by protecting the drug from enzymatic degradation and the protein nanoparticles can be used in a variety of targeted therapies including cancer therapy.

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Some proteins used for nanoparticle preparation

- Silk Protein Fibroin
- Human Serum Albumin (HSA)
- Giladin
- Gelatin
- Lipoprotein
- Ferritin
- Legumin
- 30Kc19



The slide features a video inset of a woman in the bottom right corner and logos for IIT Bombay and NPTEL at the bottom.

These [refer to slide] are some proteins that are used for nanoparticle preparation.

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Methods of preparation

1. Chemical Method – Emulsion, Complex coacervation
2. Physical Method – Nanospray drying, Electrospray
3. Self-Assembly – Desolvation



The methods of preparation include chemical methods, physical methods and even self - assembly where we have the protein nanoparticle being prepared.

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HSA Nanoparticles

Human serum albumin (HSA), a versatile protein carrier for drug delivery, is an ideal material to fabricate nanoparticles for drug delivery systems.

The most important characteristics of HSA nanoparticles are particle size, shape, and zeta potential.






For example human serum albumin nanoparticles HSA, is a versatile protein carrier for drug delivery and is an ideal material to fabricate nanoparticles for drug delivery systems, for the preparation of such systems, to not only see the protein as a protein corona on a nanoparticle, but also create the nanoparticle from HSA itself and the most important characteristics of HSA nanoparticles are their particle size, their shape and the charges that can be determined by the zeta potential.

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Summary

- Nanoparticles and the protein corona
- Impact of protein-NP interactions on biological processes
- Methods to detect protein nanoparticle interactions and applications
- Protein based nanoparticles



So in summary, we looked at nanoparticles and the protein corona, the importance of the protein corona and trying to understand how interactions can occur, the impact of protein - nanoparticle interactions on biological processes, how we can develop methods to detect protein nanoparticle interactions and their specific applications particularly in biomedicine, where we can look at bioimaging, phototherapy, dynamic or photochemical therapy and several methodologies that can be used to develop this for a nanomedicine. We also looked at protein-based nanoparticles, the advantage of being their biocompatibility and their biodegradability.

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These [refer to slide] are the references.

