Summary and Explanation of Slide 2 on BIOFOULING AND BIOGLUES

Summary

The slide presents an overview of various biological roles for slimy, sticky secretions produced by animals and plants.

Explanations

Concepts and Terms

Attachment: Examples: Starfish use sticky secretions to adhere to surfaces.
Locomotion: Examples: Snails produce mucus for smooth movement.
Defence: Examples: Slugs and certain lizards use sticky secretions to deter predators.
Hunting: Examples: Spiders and other predators use adhesives to capture prey.
Home Construction: Examples: Insects like termites use secretions to build structures.
Mating: Examples: Certain plants and animals use sticky substances in reproductive processes.

Diagrams and Data

Attachment

- Starfish use sticky secretions to adhere to surfaces.

Locomotion

- Snails produce mucus for smooth movement.

Defence

- Slugs use sticky secretions to deter predators.
- Certain lizards use sticky secretions as a defensive mechanism.

Hunting

- Spiders use adhesives to capture prey.
- Other predators use sticky secretions for hunting purposes.

Home Construction

- Insects like termites use secretions to build structures.

Mating

- Certain plants use sticky substances in reproductive processes.
- Animals may also use adhesive secretions during mating.

Notes:

- This slide highlights the versatility of biological adhesives across different species and functions.
- Specific organisms representing each category showcase the diversity in application within the natural world.
- Understanding these categories and examples is crucial for appreciating the complex role of biological adhesives in nature.

Summary and Explanation of Slide 3 on BIOFOULING AND BIOGLUES

Summary

This slide provides a definition and visual examples of biofouling.

Explanations

Concepts and Terms

Definition: Biofouling, also known as biological fouling, refers to the accumulation of microorganisms, plants, algae, or animals on wetted surfaces.

Diagrams and Data

Visuals:

- *Top Left Image:* Shows a pipe clogged with marine organisms, illustrating internal biofouling.
- *Bottom Left Image:* Displays a magnified view of biofouling on a material, highlighting the density and structure of fouling organisms.
- *Center Image:* Depicts the hull of a boat heavily covered with marine growth, an example of external biofouling on a vessel.
- *Right Image:* Cover page of the journal "Biofouling," emphasizing its scientific and research importance related to this issue.

Notes:

- Biofouling can have significant economic and operational impacts, particularly in marine industries, where it affects ship efficiency and fuel consumption.
- Understanding biofouling is crucial for developing antifouling technologies and maintenance strategies.

Summary and Explanation of Slide 4 on BIOFOULING AND BIOGLUES

Summary

The slide explains the occurrence of biofouling in the human body, showcasing various areas where biofilms can form, such as on medical devices and in the mouth.

Explanation

Concepts and Terms

Biofouling: This is the accumulation of microorganisms on wetted surfaces. In the human body, biofouling primarily refers to the formation of biofilms.
Biofilms: These are collections of microorganisms that stick to each other and to surfaces, enveloped in a protective extracellular matrix. They are significant in medical contexts as they can lead to infections and complications.

Relevant Examples

Biofilm on a Catheter

- Biofilms can form on catheters due to their constant contact with bodily fluids.
- Catheter contamination can lead to infections and other complications.

Biofilm on Teeth (Plaque)

- Plaque is a type of biofilm formed by bacteria in the mouth leading to gum disease and tooth decay if not managed properly.

Biofilm on an Orthopedic Implant

- Orthopedic implants can become contaminated with biofilms, leading to infections that may compromise the success of the implant and the patient's health.

Biofilm on a Heart Valve Implant

- Like orthopedic implants, heart valve implants can also develop biofilms, which are especially dangerous due to the critical nature of the heart's function.

Concepts

Catheter Contamination: Insertion of a catheter provides a pathway for bacteria, and the materials used can facilitate biofilm formation.
Gum Disease: Chronic inflammatory conditions caused by an overgrowth of oral bacteria forming biofilms.
Implant Contamination: Medical implants, made from materials like metals and plastics, are prone to biofilm formation, which can lead to severe infections.

Notes

- Prevention and treatment of biofilms in medical contexts often involve stringent hygiene protocols and may require the use of antibiotics or antibiofilm agents.
- The development of materials less conducive to biofilm formation is an ongoing area of research in biomedical engineering.

Understanding the impact of biofouling within the human body is essential for designing better medical devices and treatment protocols to mitigate biofilm-associated infections.

Summary and Explanation of Slide 5 on BIOFOULING AND BIOGLUES

Summary

This slide outlines various types of biofouling and their associated problems in different sectors: medical, marine, metal, and industrial.

Explanations

Concepts and Terms

Biofouling: The accumulation of microorganisms, plants, algae, or animals on wetted surfaces, leading to detrimental effects.
Medical Sector

- *Orthopaedic implant*: Biofouling can cause infections leading to implant removal.
- *Respirator*: Can result in ventilator-associated pneumonia.
- *Contact lens*: Can cause eye infections.
- *Catheter*: Can cause urinary tract infections.
- *Haemodialysis*: Can lead to infectious break-outs.
- *Teeth/dental implant*: Can cause periodontal disease and gingivitis.
- *Biosensors*: Can fail due to fibrous encapsulation.

Marine Sector

- *Ship hull*: Causes increased fuel consumption due to extra drag.
- *Ship engine*: Increases stress from extra drag.
- *Marine platform*: Leads to structural issues from load/stress/fatigue and increased biocorrosion.

Industrial and Metal Sectors

- *Membrane*: Shows reduced flux.
- *Heat exchanger*: Experiences reduced convection efficiency.
- *Fluid flow*: Suffers from frictional loss in pipes.
- *Drinking water*: Presence of pathogens in potable water.
- *Fuel*: Biofouling can cause diesel fuel contamination.
- *Food, paper, and paint industry*: Leads to food spoilage and worker health risks.
- *Metal-cutting fluid*: Results in filter blockage and worker health risks.

Notes

- Biofouling poses significant operational and health risks across various industries.
- Effective management and mitigation strategies are essential to prevent and control biofouling-related issues.

Summary and Explanation of Slide 6 on BIOFOULING AND BIOGLUES

Summary

Biofouling begins with the adsorption of molecules, often proteins, onto a surface, forming a conditioning film that facilitates the adhesion of bacteria or algae. The slide shows the progression from molecules to various organisms in different stages of biofouling.

Explanation

Concepts and Terms

Biofouling: The accumulation of microorganisms, plants, algae, or small animals on wetted surfaces, like ship hulls or underwater structures.
Conditioning Film: An initial layer formed by the adsorption of molecules on a surface, which paves the way for biofouling.
Microfouling: Initial stages involving bacteria and small organisms.
Macrofouling: Later stages involving larger organisms like tubeworms and mussels.

Diagrams and Data

Conditioning Film (Minutes to Hours)

- *Starts within Minutes*: Adsorption of proteins forming a conditioning film on the surface.
- *Within Hours*: Bacterial colonization begins, leading to microfouling.

Microfouling (Days)

- **Soft Foulers**: In a few days, soft-bodied organisms like sponges and tunicates begin to attach and grow.

Macrofouling (Weeks to Months)

- **Hard Foulers**: Eventually, harder-bodied organisms such as bryozoans and mussels adhere, causing more persistent and challenging biofouling.

Notes

- Biofouling can lead to increased drag on ships, thereby increasing fuel consumption and potentially damaging structures.
- Effective prevention and maintenance strategies are crucial in managing and mitigating biofouling.

Summary and Explanation of Slide 7 on BIOFOULING AND BIOGLUES

Summary

The slide explains how mussels adhere to surfaces using elastic protein fibers known as byssus threads, composed mainly of collagen. It highlights mussels' ability to withstand dynamic forces due to their unique fibrous architecture.

Explanations

Concepts and Terms

Byssus Threads: Elastic protein fibers that mussels use to attach themselves to surfaces.
Collagen: The main protein component in byssus threads, providing structural strength and flexibility.
Radial Distribution: The layout of byssus threads spreading out from the mussel, contributing to their adhesive strength.
Plaque: The adhesive end of the byssus thread that attaches to the surface.

Diagrams and Data

Diagram of Mussel and Byssus Threads

- *Compliant Portion*: More flexible part of the byssus thread.
- *Stiff Portion*: Less flexible part closer to the mussel.

Microscopic Image

- Shows the collagen fibers connecting to a surface.

Graph (Force vs. Displacement)

- Demonstrates the force (F) in Newtons (N) required to displace the byssus thread by a distance (Δx) in millimeters (mm).
- Indicates that the dynamic force resistance is about 9 times the static strength.

Notes:

- *Dynamic Forces*: Forces that vary with time, in contrast to static forces which are constant. The ability to withstand dynamic forces is crucial for mussels in turbulent aquatic environments.

Summary and Explanation of Slide 9 on BIOFOULING AND BIOGLUES

Summary

The slide explains how mussels adhere to surfaces using byssus threads, which are terminated with specific proteins (Mefp-1 to Mefp-6) containing high concentrations of DOPA (dihydroxyphenylalanine) groups.

Explanations

Concepts and Terms

Byssus Threads: These are fibrous threads produced by mussels to anchor themselves to surfaces in aquatic environments. The threads consist of various sections, including an elastic part and a rigid part.
Special Proteins (Mefp-1 to Mefp-6): These are mussel foot proteins that play a crucial role in adhesion. They are rich in DOPA groups, which enhance the adhesive strength of the byssus threads.
DOPA Groups: These are a key component of the adhesive properties of the proteins, contributing 12-15% of DOPA in the threads and 20-27% in the plaques.
Adhesive Plaque: This is the part of the byssus thread that attaches to the substrate, containing various Mefp proteins.
Nano Coating: Highlighted as an important feature for enhancing adhesion properties.
Phenol Glands: These glands in the byssus foot secrete the adhesive proteins.

Notes

- **Mefp Proteins**: Mefp-5 and Mefp-3 are particularly known for their strong adhesive properties.
- **Application**: Understanding mussel adhesion mechanisms is valuable for developing bio-inspired adhesives and preventing biofouling.

This slide provides important insights into the biochemical and structural mechanisms by which mussels adhere to surfaces, relevant to both biofouling and the development of bioglues.

Summary and Explanation of Slide 10 on BIOFOULING AND BIOGLUES

Summary

The slide discusses L-DOPA, a special amino acid variant of phenylalanine, detailing its role and structural relevance in biofouling and bioglue applications.

Explanations

Concepts and Terms

L-DOPA (Levodopa):
A variant of the amino acid phenylalanine, known chemically as L-3,4-dihydroxyphenylalanine

Role in Biofouling:
L-DOPA is part of the adhesive proteins in mussels, facilitating their attachment to substrates. Specific proteins (Mefp-1, Mefp-2, Mefp-3, Mefp-5) in mussels contain DOPA residues which contribute to strong adhesion.

Chemical Structures:
The slide shows structural formulas of phenylalanine, DOPA, and dopamine. Catechol (highlighted in red) is a key functional group in DOPA and dopamine, essential for adhesion properties.

Diagrams and Data

Mussel Adhesion Layout

- Images detail how mussels use adhesion proteins (Mefp's) containing DOPA interacting with substrates.

Protein Sequences

- Specific sequences from Mefp proteins highlight locations of DOPA (Y) residues.

Notes:

- **Application**: DOPA's adhesive properties are studied for developing synthetic bioglues.
- **Terminology**: Catechol: Essential aromatic compound important for adhesion.

Summary and Explanation of Slide 11 on BIOFOULING AND BIOGLUES

Summary

The slide discusses DOPA-surface interactions during deposition at low pH, detailing both interfacial and cohesive interactions.

Explanations

Concepts and Terms

DOPA-Surface Interactions: DOPA (3,4-dihydroxyphenylalanine) is critical in bioadhesion. The slide illustrates the various types of interactions that DOPA experiences during deposition on surfaces, particularly at low pH.
Interfacial Interactions: 1. *H-bond (Hydrogen Bonding)*: DOPA's hydroxyl groups interact with surface oxides.
2. *Electrostatic*: DOPA's carboxylate group interacts with positively charged NH_3^+ and Ca^{2+} ions.
3. *Hydrophobic Interactions*: Non-polar portions like alkyl groups interact with each other to minimize contact with water.
4. *Coordination (Covalent Bonding)*: DOPA's catechol moiety coordinates with metal ions (M^{3+}) on the surface.
Cohesive Interactions: 1. *H-bond*: Similar hydrogen bonding as in interfacial interactions.
2. *Cation-π Interactions*: Positively charged ammonium groups (NH_3^+) interact with the π-electron systems of aromatic rings.
3. *Electrostatic*: Ionic interactions between charged groups on different DOPA

molecules.
4. *Hydrophobic*: Interactions among non-polar groups within DOPA molecules.

Diagrams and Data

Conceptual Diagram of DOPA-Surface Interactions

- Illustration of hydrogen bonding, electrostatic, hydrophobic, and covalent bonding at low pH.

Conceptual Diagram of DOPA-DOPA Interactions

- Illustration of hydrogen bonding, cation-π, electrostatic, and hydrophobic interactions.

Notes

- These interactions are significant in understanding the adhesive properties of DOPA-containing molecules which are prevalent in marine bioadhesives and bioglues.
- Coating and applications where biomimetic adhesives are used can benefit from understanding these molecular interactions.

Summary and Explanation of Slide 12 on BIOFOULING AND BIOGLUES

Summary

The slide discusses DOPA-surface interactions, focusing on adhesion and cohesion mechanisms involving DOPA.

Explanations

Concepts and Terms

DOPA (Dihydroxyphenylalanine): An amino acid found in mussel adhesive proteins responsible for strong adhesive properties.
Adhesion: Interaction of DOPA with surfaces at different pH levels:

- *pH 2*: Two hydrogen bonds (H-bonds).
- *pH 5*: H-bond and coordination.
- *pH 8*: Bidentate coordination (DOPA can interact with metal ions in a surface, forming strong coordination bonds).

Cohesion: Interaction of DOPA units with each other via Fe(III) ions:

- *Mono*: Single DOPA unit binding with one Fe(III) ion.
- *Bis*: Two DOPA units binding with Fe(III).
- *Tris*: Three DOPA units binding with Fe(III).

Notes:

- The effectiveness of DOPA in adhesion is dependent on the pH of the environment, altering the type of bonding.
- Cohesive interactions via Fe(III) can enhance the mechanical properties of bioglues by forming crosslinked networks.

This slide describes how the adhesive and cohesive properties of DOPA are significant for bioadhesive applications, particularly in varying environmental pH conditions.

Summary and Explanation of Slide 13 on BIOFOULING AND BIOGLUES

Summary

This slide discusses DOPA (dopamine) coatings that can bind to a wide variety of surfaces. The DOPA molecules auto-polymerize and form coatings that can be up to 50 nm thick.

Explanations

Concepts and Terms

DOPA Molecules: Dopamine can polymerize to form polydopamine. Capable of binding to many types of surfaces.
Auto-Polymerization: Process where dopamine self-assembles into a polymer coating without the need for additional chemicals or conditions.
Coating Thickness: The auto-polymerized coatings formed by DOPA can reach up to 50 nm in thickness over a period of time. Thickness increases over time, as depicted in the graph (left).

Diagrams and Data

Left Diagram

- Shows an uncoated object being dipped in a dopamine solution (pH 8.5) and emerging as a polydopamine-coated object

- Plot of coating thickness (nm) vs. time (hours) indicates the growth of the polydopamine layer over a 25-hour period, with a plateau reached around 20 hours.

Right Graph

- Demonstrates the substrate signal percentages and the N/C ratio for various surfaces coated with DOPA.
- The bar graph shows consistent coating effectiveness across numerous materials except for a few (marked N.A. - detection method failures).

Notes:

- *Detection Method*: Indicates certain materials (like PE, PTFE, PMMA, etc.) where the method to detect the DOPA coating failed, rather than the coating itself failing.
- *Experimental Basis*: The data and findings are based on research published by Lee et al. in *Science* (2007).

Summary and Explanation of Slide 14 on BIOFOULING AND BIOGLUES

Summary

The slide discusses DOPA-mediated metal coatings, demonstrating how a primary coating of DOPA applied to synthetic objects allows for stable deposition of a secondary copper coating.

Explanations

Concepts and Terms

DOPA (3,4-Dihydroxyphenylalanine): A molecule that can facilitate the adhesion of coatings on various surfaces.
It plays a critical role in the formation of bio-adhesives, inspired by mussel adhesive proteins.
Metal Coatings: A process that involves applying a metal layer onto a surface to enhance its properties, such as corrosion resistance or electrical conductivity.

Explanation

Primary Coating of DOPA

- DOPA can be applied as a primary layer onto various synthetic materials including nitrocellulose film, coins, and plastic dice.

Secondary Copper Coating

- Once the DOPA layer is applied, copper can be stably deposited as a secondary coating on these objects.
- The images in the slide provide visual evidence of the copper coating on different objects.

Notes

- This method mimics natural processes observed in marine organisms like mussels, which use similar compounds to adhere to surfaces in wet environments.
- The use of DOPA in coatings can have practical applications in biotechnology, electronics, and materials science for creating durable and stable metal coatings on a variety of surfaces.

Summary and Explanation of Slide 15 on BIOFOULING AND BIOGLUES

Summary

The slide explains the process of creating DOPA-mediated hyaluronic acid (HA) coatings to improve cell adhesion on polystyrene surfaces. It details a two-step process involving dopamine dip-coating and the addition of HA.

Explanations

Concepts and Terms

DOPA (Dopamine): A molecule used for surface coating to facilitate further biochemical modifications.
Hyaluronic Acid (HA): A biomolecule known for its ability to enhance cell adhesion.
Polystyrene: A plastic material often used in labware which can benefit from surface modification to improve biocompatibility.

Process Explained

Step 1: Dip-coating in Dopamine

- Submerge the polystyrene surface in a dopamine solution. This forms a primary layer on the surface.

Step 2: Adding Hyaluronic Acid (HA)

- After the dopamine layer is established, hyaluronic acid is added to the surface. This forms a biocompatible coating that enhances cell adhesion.

Diagram

The left side of the slide depicts the two-step coating process:

- Dip-coating in dopamine.
- Coating with HA.

The right side shows a graph plotting "Fraction adherent cells" against "HA concentration (mg/mL)," indicating that higher HA concentrations on the coated surface result in increased cell adhesion.

Notes

- This coating technique can significantly improve the biocompatibility of synthetic surfaces, which is crucial in biomedical applications.

Summary and Explanation of Slide 16 on BIOFOULING AND BIOGLUES

Summary

The slide discusses selective filtration using macromolecular coatings, highlighting a PDMS filter mimicking cotton candy structures for its filtration function.

Explanations

Concepts and Terms

PDMS: Polydimethylsiloxane, a type of silicone used here as a filter medium.
Cotton Candy: Used as an analogy to depict the structure of the PDMS filter.
Filtration: The process of separating particles from a fluid.

Diagram and Data

Diagram:

- Shows a visual and microscopic view of the PDMS filter, emphasizing its structure.

Average Capillary Diameter (d):

- 8.26 um, indicating the size of the pores.

Capillary Density (n):

- 595 mm^{-2}, showing the number of capillaries per square millimeter.

Volume (V):

- 133 mm^3, the total volume of the filter.

Flow Velocity in Capillaries (v):

- 5.2 mm/s, speed of fluid movement.

Reynolds Number (Re):

- 0.04, a dimensionless number indicating laminar flow.

Flow Resistance (Δp):

- 365 mbar, indicating the pressure drop across the filter.

Notes

- The slide is based on a study from *Macromolecular Bioscience (2018)* by Winkeljann et al.
- The selective filtration mechanism relies on the narrow and dense capillaries of the PDMS, similar to the structure of cotton candy, effectively filtering particulates from fluids.

Summary and Explanation of Slide 17 on BIOFOULING AND BIOGLUES

Summary of Slide Content

This slide discusses the selective filtration properties of macromolecular coatings, specifically focusing on poly-L-lysine (PLL) and mucin adhering to PDMS. It presents filtration tests using different liposomes and dextrans.

Explanation

Concepts and Terms

Selective Filtration: The process of selectively allowing certain molecules to pass through a filter while blocking others.
Macromolecular Coatings: Large molecular substances like PLL and mucin used to coat surfaces to control filtration properties.

Terms

PLL (Poly-L-lysine): A polymer used to create a positive charge on the surface, facilitating high-pass filtration.
Mucin: A protein that provides a low-pass filter due to its structure and properties when adhered to PDMS (Polydimethylsiloxane).
PDMS (Polydimethylsiloxane): A silicone compound used as a base material for coating.
Liposomes: Small spherical vesicles used in filtration tests to study how different coatings affect movement through filters.
Dextrans: Complex branched glucans used to analyze filtration properties of the coatings.

Diagrams and Graphs

Graph on the Left (Poly-L-lysine)

- Shows high-pass filtration, meaning higher passage of liposomes (DOPC, DOTAP) that carry a positive charge while limiting passage of negatively charged liposome (DOPG).
- Y-axis: Fraction of liposomes passing the filter [%].
- X-axis: Types of liposomes (-: negative charge, +/-: neutral, +: positive charge).

Graph in the Middle (Mucin)

- Indicates low-pass filtration, showing higher passage for neutral and negatively charged liposomes (DOPC, DOPG) but very limited passage for positively charged liposomes (DOTAP).
- Y-axis: Fraction of liposomes passing the filter compared to an unfiltered reference [%].
- X-axis: Types of liposomes.

Graph on the Right (Dextrans)

- Demonstrates selective filtration properties with dextran molecules through different surfaces (CM, unmod., DEAE).
- Y-axis: Fraction of molecules passing the filter [%].
- X-axis: Types of coated surfaces (CM: carboxymethyl, unmod.: unmodified, DEAE: diethylaminoethyl).

Illustration

Illustration to the Right: Visual representation of the experimental setup showing how liposomes are filtered through the PDMS surface coated with macromolecular substances.

Notes:

- The specific conditions and overall performance of this selective filtration can be highly influenced by the characteristics of the applied coatings and their interaction with PDMS.
- Further experimental details might include the measurement methods, sample preparation, and control conditions to validate the findings.

Summary and Explanation of Slide 18 on BIOFOULING AND BIOGLUES

Summary

The slide explains how DOPA (dopamine)-pre-coating immobilizes non-adhesive macromolecules (such as PEG) to enable selective filtration through specific interactions, exemplified by the biotin-streptavidin interaction.

Explanations

Concepts and Terms

DOPA-pre-coating: A coating process using dopamine that can immobilize non-adhesive macromolecules.
PEG (Polyethylene Glycol): A non-adhesive macromolecule used in the coating.
Biotin-streptavidin Interaction: A specific binding interaction between biotin and streptavidin used to demonstrate the filtration process.
Streptavidin Liposomes: Vesicles used in the experiment tagged with streptavidin.
PDMS (Polydimethylsiloxane): A silicone-based organic polymer used in the experimental setup.

Diagrams and Data

Schematic Diagram

- Shows how the PDMS layer is coated with dopamine and PEG, enabling specific interactions that trap biotin-streptavidin complexes while allowing other molecules to pass through.

Graph

- Depicts the fraction of liposomes (vesicles) passing through the filter.
- Biotin-labeled liposomes pass the filter in higher quantities compared to streptavidin-labeled liposomes, indicating the selective filtration properties based on specific interactions.

Notes

- *Biotin-Streptavidin System*: Frequently used in biochemistry and molecular biology for its high affinity and specificity, often exploited to attach or purify proteins, nucleic acids, and other molecules.
- *Applications*: Understanding and employing such selective filtration can be crucial in designing targeted delivery systems, biosensors, and other biotechnology applications.

Summary and Explanation of Slide 19 on BIOFOULING AND BIOGLUES

Summary

The slide explains surface coating strategies using catechols through two methods: “graft to” and “graft from.”

Explanations

Concepts and Terms

Catechols: Organic compounds with two hydroxyl groups attached to a benzene ring, involved in strong adhesive properties.
Graft to Coating Method: Catechol-conjugated polymers adsorb onto the surface where the catechol groups interact with the substrate, forming a coating.
Graft from Coating Method: An initiator immobilizes onto the surface first, followed by polymerization of monomers to form a catechol-functionalized coating.

Diagrams and Data

Left (Graft to Coating Method)

- Shows catechol-conjugated polymers interacting directly with the surface leading to adsorption.

Right (Graft from Coating Method)

- Details a two-step process where an initiator is immobilized first onto the surface, and then polymerization of the monomers occurs to form the final catechol-containing polymer coating.

Notes:

- These methods are significant in creating durable and effective antifouling and adhesive surfaces.
- The citation provides the original study from Forooshani and Lee in *J. Polym. Sci., Part A: Polym. Chem.* (2017) for further reading.

Summary and Explanation of Slide 20 on BIOFOULING AND BIOGLUES

Summary

The slide discusses dopamine-based multilayers in bioadhesion applications, presenting a method involving dopamine and biopolymer interactions.

Explanation

Dopamine-Based Multilayers

Dopamine A small molecule used in coating applications due to its strong adhesive properties.
Biopolymer Large, naturally occurring molecules in living organisms. In this context, biopolymers (e.g., Alginate, Dextran, PDL) are combined with dopamine to form multilayers.

Graph Analysis

The graphs display frequency changes (Δf [Hz]) over time (Δt [min]) for three different biopolymers (Alginate, Dextran, PDL).
Frequency Shift (Δf) Represents the mass related changes during the formation of multilayers on a surface.

- **Steps/Plateaus**: Indicate the addition of layers and the stability during the incubation cycles (multiple cycles are showing possible repeated layer formation).

Incubation Cycles

The number of cycles indicates how many times dopamine and biopolymer are applied in an alternating fashion.
Each cycle involves adsorption and reaction of dopamine with the surface following by layering of the biopolymer.

Notes

- **Importance of Dopamine-Based Multilayers**: These are crucial in biofouling prevention and enhancing adhesion in biological and medical devices.
- **Experimental Conditions**: The labels W, D, BP may indicate wash, dry, and biopolymer phases in the experiment.
- **Practical Applications**: This slide highlights the practical use of dopamine in creating durable, adhesive multilayers with various biopolymers for bioadhesion and implant applications.

Summary and Explanation of Slide 21 on BIOFOULING AND BIOGLUES

Summary

This slide presents data about the effect of adding multiple biopolymer layers on surface zeta potential and cell attachment efficiency of dopamine-based multilayers.

Explanations

Concepts and Terms

Surface Zeta Potential: The left graph shows surface zeta potential (measured in mV) for alginate, dextran, and PDL across one, two, and three biopolymer layers.
Key Insights:

- The surface zeta potential does not change significantly with the addition of more layers (as indicated by ”n.s.” - not significant).
- Dopamine and the substrate provide a baseline for comparison.

Cell Attachment Efficiency: The right graph displays cell attachment efficiency (percentage) for the same polymers and number of layers.
Key Insights:

- Alginate layers show a significant increase in cell attachment efficiency with more layers (* indicates significance).
- Dextran and PDL do not show significant differences between one, two, and three layers except for a slight increase in PDL at three layers.

Diagrams and Data

Graph 1: Surface Zeta Potential

- Description: The left graph shows surface zeta potential (measured in mV) for alginate, dextran, and PDL across one, two, and three biopolymer layers.
- Key Insights:
  - The surface zeta potential does not change significantly with the addition of more layers (as indicated by "n.s." - not significant).
  - Dopamine and the substrate provide a baseline for comparison.

Graph 2: Cell Attachment Efficiency

- Description: The right graph displays cell attachment efficiency (percentage) for the same polymers and number of layers.
- Key Insights:
  - Alginate layers show a significant increase in cell attachment efficiency with more layers (* indicates significance).
  - Dextran and PDL do not show significant differences between one, two, and three layers except for a slight increase in PDL at three layers.

Notes:

- *Implications*: This could indicate that the physical structure or other properties of the multilayers, rather than charge, play a crucial role in mediating cell attachment.
- **Statistical Significance**: "*" denotes statistical significance, indicating a reliable effect, while "n.s." indicates a lack of significant change.

Summary and Explanation of Slide 22 on BIOFOULING AND BIOGLUES

Summary

The slide discusses the properties of dopamine-based multilayers with respect to friction and drug release, using alginate, dextran, and PDL as materials.

Explanations

Friction

The three bar graphs at the top show the friction factor for alginate, dextran, and PDL at different sliding velocities (0.1 mm/s).
The friction factor for each material decreases in the darker bars compared to the lighter bars, indicating that dopamine modification reduces friction.

Drug Release

The lower set of graphs depict drug release profiles for each material (alginate, dextran, PDL) over time (in hours).
X-axis: Time (hours)
Y-axis: Released Rif (μg/mL)
Drug release appears relatively stable after an initial increase, with PDL releasing the most drug over 25 hours, followed by dextran and alginate.

Notes

Alginate

- A biopolymer derived from brown seaweed used in various biomedical applications.

Dextran

- A biopolymer made from the sugar glucose, used in drug delivery and other medical applications.

PDL (Poly-D-Lysine)

- Commonly used to coat surfaces to promote cell adhesion in medical and biological research.

Rif (likely Rifampicin)

- An antibiotic used to treat bacterial infections.

Summary and Explanation of Slide 23 on BIOFOULING AND BIOGLUES

Summary

The slide discusses the potential of creating bulk materials using catechol-based chemistry, particularly artificial hydrogels with catechol cross-links.

Explanations

Concepts and Terms

Artificial Hydrogels: Hydrogels are networks of polymer chains that are hydrophilic, often used in various applications like drug delivery and wound care, due to their ability to retain water.
Catechol Cross-links: Catechol is an aromatic compound found in various natural materials, known for its strong adhesion properties.
Synthetic Polymer with Terminal Catechols: This refers to a lab-created polymer that has catechol groups at its ends which can form cross-links.
Self-Healing Mechanism: The diagram suggests that hydrogels containing catechol are capable of self-healing. Upon cutting, the catechol groups at the fracture surface interact, allowing the material to heal itself.
Supramolecular Interactions: These are interactions at the molecular level, important for the self-healing property.
Complexation: Framework of the lower diagram indicates various types of complexes formed by catechols:

- **Complex with Metal Ions (A)**
- **Complex with Boronic Acid (B)**

- **Hydrogen Bonds between Catechol Groups (C)**

Diagrams and Data

Top Right Diagram: Shows synthetic polymer with terminal catechols becoming a self-healing hydrogel due to supramolecular interactions.

- **A**: Bonds with metal ions, which can add strength and stability.
- **B**: Interaction with boronic acid, forming strong covalent bonds.
- **C**: Hydrogen bonds between catechol groups, contributing to adhesion and cohesive properties.

Bottom Diagram: Illustrates three types of interactions involving catechols:

- **A**: Bonds with metal ions, which can add strength and stability.
-
- **B**: Interaction with boronic acid, forming strong covalent bonds.
- **C**: Hydrogen bonds between catechol groups, contributing to adhesion and cohesive properties.

Notes:

- **Relevance to Biofouling and Bioglues**: Catechol chemistry is essential in creating strong, adhesive, and sometimes self-healing materials, making it relevant to biofouling (where materials resist unwanted biological accumulation) and bioglues (where strong adhesion is required in biological contexts). - **Research Citation**: Holten-Andersen et al., PNAS (2011) - This paper likely explores more on the chemistry and applications of catechol-based hydrogels.

Summary and Explanation of Slide 24 on BIOFOULING AND BIOGLUES

Summary

The slide discusses artificial hydrogels based on catechol cross-links formed by interactions with multi-valent metal ions. It highlights the formation process, pH effects, and self-healing capabilities.

Explanations

Concepts and Terms

Catechol Cross-Links: Catechol groups interact with multi-valent metal ions to form strong cross-links, essential for hydrogel structural integrity.
Multi-Valent Metal Ions: Ions such as VCl_3, $FeCl_3$, and $AlCl_3$ form multiple bonds, facilitating cross-linking with catechol groups.
Hydrogels: Networks of hydrophilic polymer chains that can hold large amounts of water, formed by catechol-metal ion cross-linking.
cPEG: Catechol-functionalized polyethylene glycol, a polymer used in hydrogel creation.
pH Influence:

- Lower pH (*approximately 5*) results in a different structural state than higher pH (*approximately 12*).
- Hydrogels transition between states with pH changes, affecting their properties.

Self-Healing: The hydrogel can repair itself after damage, as shown in the slide's time-lapse images from 0 seconds to 3 minutes.

Diagrams and Data

Hydrogel Formation

- Images show hydrogels formed using different metal salts.
- Mixing metal salts (VCl_3, $FeCl_3$, $AlCl_3$) with cPEG and raising pH to 8 results in a hydrogel.

Chemical Structures

- Illustrations of catechol groups cross-linked with metals, showing mono-complex, bis-complex, and tris-complex structures.

pH Effect on Hydrogels

- Images depict hydrogel physical states at pH *approximately 5* and pH *approximately 12*.

Self-Healing Sequence

- Time-lapse images showing the hydrogel's self-repair.

Notes:

- Catechol-based hydrogels' cross-linking and self-healing properties make them useful for bioadhesives and tissue engineering.
- Hydrogel stability is influenced by environmental pH, impacting practical application performance.

Summary and Explanation of Slide 25 on BIOFOULING AND BIOGLUES

Summary

The slide discusses a DOPA-based thermoresponsive glue, an activatable adhesive formed by mixing DOPA-functionalized polymers with cross-linking agents using temperature-sensitive liposomes.

Explanation

Concepts and Terms

DOPA-functionalized Polymers: These polymers are modified with DOPA (dihydroxyphenylalanine) to facilitate strong adhesive properties.
Cross-linking Agents: Chemicals that bond polymer chains together to form a stable structure. In this case, they are enclosed within liposomes.
Liposomes: Small vesicles that act as carriers for the cross-linking agents. These are designed to burst or become leaky when the temperature exceeds a certain threshold.
Thermoresponsive Mechanism: When the temperature rises, the liposomes release the cross-linking agents, causing the DOPA-functionalized polymers to bond and form a glue on demand.

Notes

- *Temperature Sensitivity*: The key feature is the temperature-triggered mechanism which allows for controlled activation of the glue.
- *Application Insight*: Useful in scenarios where adhesive properties need to

be activated under specific conditions, such as in biomedical or industrial settings.

Summary and Explanation of Slide 26 on BIOFOULING AND BIOGLUES

Summary

The slide discusses *DOPA-based thermoresponsive glue* used for surgical applications as an alternative to stitching, showing significant improvements over current fibrin glue.

Explanation

Concepts and Terms

DOPA-Based Glue: DOPA (dihydroxyphenylalanine) is used in bioglue due to its adhesive properties, derived from the natural adhesive of mussels.
Thermoresponsive: The glue responds to temperature changes, affecting its adhesive qualities.

Diagrams and Data

Cross-Linker Release vs. Temperature (Left Graph)

- X-Axis: Temperature (°C).
- Y-Axis: Cross-linker release, which is a measure of how the glue's bonding changes with temperature.
- Observation: There is a significant release around 37-45°C, ideal for body temperature applications.

Storage Modulus vs. Time (Right Graph)

- X-Axis: Time (seconds).
- Y-Axis (left): Storage Modulus (Pa), indicating the stiffness of the glue.
- Y-Axis (right): Temperature (°C).
- Observation: Sharp increase in storage modulus around 1000s, indicating solidification and strong bonding at the tested temperature (around 37°C).

Shear Strength Comparison (Bottom Graph)

- X-Axis: Comparison between PEG-$DOPA_4$-PCVs and commercial fibrin glue.
- Y-Axis: Shear Strength (kPa).
- Observation: The PEG-$DOPA_4$ bioglue shows a significantly higher shear strength (~45 kPa) compared to commercial fibrin glue (~10 kPa).

Notes:

- *Application*: This bioglue could be used in surgeries to replace stitching, providing stronger and potentially more reliable joining of tissues.
- **Lab Test**: The strength test involved gluing porcine (pig) skin samples, which are often used as a model in biomedical research.
- **Advantage**: The catechol-based bioglue presents a tenfold higher shear strength than traditional fibrin glue, indicating it could be a more effective adhesive for surgical purposes.

Summary and Explanation of Slide 27 on BIOFOULING AND BIOGLUES

Summary of the Slide

The slide discusses bilayer films designed for broad-range tissue adhesion, consisting of two layers: an upper layer of PVA/mucin blend and a lower layer of dopamine-HA conjugates.

Explanation

Concepts and Terms

Bilayer Films: These are films composed of two distinct layers, each contributing different properties to enhance overall functionality.
PVA (Polyvinyl Alcohol): A synthetic polymer that is highly compatible with biological tissues.
Mucin: A glycoprotein component that improves tissue adhesion and mimics natural tissue environments.
Dopamine-HA (Hyaluronic Acid) Conjugates: A compound combining dopamine, known for its strong adhesive properties, with hyaluronic acid, which promotes tissue repair and hydration.

Processes

Electrospraying: A technique used to create the upper layer by dispersing a PVA/mucin blend into a fine mist using an electric field, which deposits evenly onto a surface.

Casting: A method used to form the lower layer by pouring a mixture of dopamine-HA onto a surface and allowing it to solidify.

Diagrams and Data

Electrospraying Setup

- Illustrates the equipment used to deposit the PVA/mucin blend layer.

Tissue Adhesion Illustration

- Demonstrates how the bilayer film adheres to damaged tissue, providing mechanical robustness, anti-inflammatory, and anti-bacterial properties, while also facilitating advanced wound healing through unidirectional drug release.

Notes

- *Anti-inflammatory and Anti-bacterial Properties*: The bilayer film helps in reducing inflammation and bacterial infection at the site of tissue application.
- *Mechanically Robust*: The film is strong enough to stay intact and functional during the healing process.
- *Advanced Wound Healing*: The bilayer promotes faster and more efficient wound healing due to its composition and drug release capabilities.

Summary and Explanation of Slide 28 on BIOFOULING AND BIOGLUES

Summary

The slide discusses the stability and adhesion behavior of bilayer films, focusing on their mechanical properties and their ability to adhere to various tissues.

Explanations

Concepts and Terms

Bilayer Films: These are composite materials comprising two distinct layers.
Upper Layer: Increases the structural stability of the construct.
Lower Layer: Enhances adhesion to different tissues.

Mechanical Properties:
Elongation at Break (%): The extent to which the material can stretch before breaking.

- Bilayer: $3.4 \pm 1.6\%$
- d-HA: $3.1 \pm 0.8\%$
- PVA/mucin: $54.2 \pm 4\%$

Max. Rupture Force (N): The maximum force the material can withstand before breaking.

- Bilayer: 9.1 ± 3 N
- d-HA: 4.6 ± 2 N
- PVA/mucin: 1.1 ± 0.5 N

Diagrams and Data

Graphs and Data

- The **top-right graph** shows the relationship between stretching force (N) and displacement (mm) for bilayer, d-HA, and PVA/mucin.
- The **bar chart** at the bottom shows detachment forces (N) for different tissues (eye, tongue, intestine, cartilage), indicating how well the lower layer adheres to these tissues.

Notes

- *Elongation at break* is a measure of the ductility of a material; higher values indicate greater flexibility.
- *Max. rupture force* indicates material strength, with higher values representing greater strength.
- The *detachment force* indicates the adhesive strength of the lower layer to various tissues, with higher bars indicating stronger adhesion.

Understanding these properties helps in evaluating the suitability of bilayer films for medical and bioadhesive applications.

Summary and Explanation of Slide 29 on BIOFOULING AND BIOGLUES

Summary

The slide discusses the use of bilayer films for drug release and wound healing, presenting various experimental results and their impact on different parameters related to wound healing in an animal model.

Explanations

Concepts and Terms

Bilayer Films: Composed of Polyvinyl Alcohol (PVA)/Mucin (MUC) and d-Hyaluronic Acid (d-HA), these are used for controlled drug release and wound healing applications.
Diffusion Setup: Describes the experimental setup where the bilayer film is placed between donor and acceptor chambers to study drug release. Samples are taken from both chambers.
Cumulative Release Graph: Shows the percentage of drug released over time in PBS (Phosphate Buffered Saline), indicating a controlled, gradual release.

Diagrams and Data

Epidermis Thickness

- *Y-Axis*: Thickness in micrometers (μm).
- *Comparison*: Healthy skin tissue, untreated wound, Janus film, drug-loaded Janus film across days 3, 7, and 14.

- *Observation*: The drug-loaded Janus film showed a more significant increase in epidermis thickness over time.

Number of Hair Follicles

- *Y-Axis*: Number of hair follicles.
- *Comparison*: Categories as above.
- *Observation*: Drug-loaded Janus films appear to promote hair follicle formation most effectively over time.

Collagen Index

- *Y-Axis*: Percentage (%).
- *Comparison*: Categories as above.
- *Observation*: Collagen index is highest in the presence of the drug-loaded Janus film, indicating better wound healing.

Notes:

- The red asterisks (*) in the graphs indicate statistically significant differences.
- n.s. indicates no significant statistical difference.

This slide provides a thorough explanation of how bilayer films can be utilized in biomedical applications, specifically for controlled drug release and enhancement of wound healing parameters.

Summary and Explanation of Slide 30 on BIOFOULING AND BIOGLUES

Summary

This slide explains the mechanism behind dry surface adhesion utilized by geckos.

Explanation

Macrostructure, Mesostructure, Microstructure

The images show different structural levels of a gecko's foot, highlighting how its adhesion mechanism works.
Macrostructure: Refers to the entire foot of the gecko.
Mesostructure: Shows a closer view of the foot, including the toe pads.
Microstructure: Displays an even closer perspective, revealing fine details of the foot's surface.

Fine Microstructure and Nanostructure

These images dive deeper into the microscopic and nanoscopic levels.
Fine Microstructure: Shows the arrangement of setae (bristle-like structures).
Nanostructure: Further zooms into the spatulae (ends of the setae) which are very thin (approximately 200 nm in thickness).

Concepts

Van der Waals Forces: Weak intermolecular forces that contribute to the gecko's ability to adhere to surfaces. Each spatula creates multiple weak adhesive interactions with a surface, collectively generating a strong adhesive force.

Notes

- The gecko's ability to stick to surfaces without liquids or adhesives is primarily due to the large number of spatulae, which increase the overall contact area and enhance adhesion through van der Waals interactions.

Summary and Explanation of Slide 31 on BIOFOULING AND BIOGLUES

Summary

The slide presents a combined bio-inspired wet/dry adhesive derived from gecko and mussel adhesion mechanisms. It includes the process of fabricating the adhesive, microstructural images, and experimental data on its adhesive performance.

Explanations

Concepts and Terms

Fabrication Process:
Electron-beam lithography: Used to create a pattern on PMMA (Polymethyl methacrylate) on a silicon substrate.
PMMA/Si master: Patterning process continues, forming a template.
PDMS (Polydimethylsiloxane) casting: A negative mold is created from the PMMA/Si master.
Lift-off process: The final structure with 600 nm height and 400 nm width pillars is created.

Bio-Inspired Design:
Gecko Adhesion: Gecko-inspired structures with nanotips for dry adhesion.
Mussel Adhesion: Bio-chemical properties of mussel adhesive proteins to function in wet conditions.

Diagrams and Data

Adhesion Testing via AFM (Atomic Force Microscopy)

- *Graph (Top right)*: Comparison of individual pillar force (in nanonewtons) in air and water between gecko and geckel adhesives.
- *Graph (Bottom right)*: Force (in newtons) relative to the number of pillars, showing combined performance.

Microstructural Images

- *10 μm scale image*: Detailed view of the structure of the adhesive pillars that mimic the gecko's footpad.

Notes:

- **Combined adhesive properties**: The study shows that geckel adhesives perform well in both dry and wet environments, showcasing the hybrid functionality derived from both gecko and mussel mechanisms.
- **Reference**: Lee et al., Nature (2007)

Understanding these bio-inspired adhesives may provide innovative solutions for adhesive technologies in various environmental conditions.

Summary and Explanation of Slide 32 on BIOFOULING AND BIOGLUES

Summary

The slide provides examples of biological adhesives derived from carbohydrates. It lists natural sources of these adhesives and the modified biomolecules created from them.

Explanation

Molecular Class: Carbohydrates

Examples from Nature: Starch, alginate, cellulose, fucoidan, tannic acid, acacia gum, sundew mucilage (myo-inositol), pollenkitt (viscin), propolis.

Adhesives Created via Modification of Biomolecules:

- *Propionylated Amylose*: A modified form of amylose (a component of starch), which is propionylated to enhance its adhesive properties.
- *Boronic Acid Conjugated Alginate*: Alginate modified with boronic acid to improve its adhesive functionality.
- *Cellulose-Phenylboronic Acid Conjugate*: Cellulose combined with phenylboronic acid for adhesive uses.
- *Alginate Crosslinked by Organosilane*: Alginate chemically crosslinked using organosilane compounds to strengthen its adhesive properties.
- *Tannic Acid as Crosslinker for Chitosan*: Tannic acid used to crosslink chitosan, enhancing the adhesion and mechanical properties.

- *Cross-Linking by Functionalization with Methacrylate Groups*: Innovative cross-linking technique involving methacrylate groups to create robust adhesives.

Notes

- **Carbohydrates as Adhesives**: Carbohydrates form the basis for many natural adhesives. When modified, they can achieve enhanced properties useful in various applications, including medical and industrial.
- **Modification Techniques**: Chemical modifications such as propionylation, conjugation with boronic acid, and cross-linking using various agents and methods are key to developing effective bioglues from natural sources.

These adhesive examples highlight the versatility and potential of natural biomolecules when chemically tailored for specific uses.

Summary and Explanation of Slide 33 on BIOFOULING AND BIOGLUES

Summary

The slide discusses how the seeds of **Plantago lanceolata** secrete a slimy mucilage containing cellulose (blue) and pectin (red) when wet. This mucus contributes to increased adhesion forces over time as the seed mucilage dries.

Explanation

Plantago lanceolata Seeds

These seeds excrete a mucilage when wet, which is made up of cellulose and pectin.
The blue color indicates the presence of cellulose, and the red color shows the presence of pectin.
The adhesion force of the wet seeds starts between 15 to 30 milliNewtons (mN) and increases as the mucilage dries out.
The graph displays the adhesion force (F_{ad} in mN) over time (in minutes) for five different seeds. The trend shows that the adhesion force peaks and increases as the mucilage dries.

Notes:

- The images on the left display microscopic views of the wet mucilage stained for cellulose (blue) and pectin (red).
- The graph indicates that each seed exhibits different adhesion properties over

time, which is crucial for understanding the variability and dynamics of bioadhesion in natural settings.

This information is vital for understanding the role of plant mucilage in biofouling and bioglues.

Summary and Explanation of Slide 34 on BIOFOULING AND BIOGLUES

Summary

The slide explains the process of rendering wood sticky through delignification, specifically with beech wood.

Explanations

Concepts and Terms

Beech Wood: The raw material used in this process.
Delignified Beech Wood: Beech wood that has had its lignin content reduced, making it stickier.
Chemical Treatment: The beech wood is treated with hydrogen peroxide (H_2O_2) and acetic acid at 90°C for 5 hours, then washed overnight and air-dried.
Sdr: A parameter indicating the surface roughness or area ratio of the delignified wood sample, with a value of 140% ± 40%.

Diagrams and Data

Photographs

- Images of the beech wood before and after the delignification process.

Scanning Electron Microscope (SEM) Image

- Shows the texture and increased surface area of the delignified wood, providing a detailed view of the structural changes at the microscopic level.

Data on Surface Roughness (Sdr)

- Indicates that the delignified sample has 140% ± 40% more surface area compared to before treatment.

Notes

- Delignification is the process of removing lignin from wood, which enhances its adhesive properties.
- Increased surface area (Sdr) is beneficial for creating sticky surfaces, relevant in applications like bioglues.

Summary and Explanation of Slide 35 on BIOFOULING AND BIOGLUES

Summary

This slide describes an experiment aimed at increasing the adhesive properties of beech wood using a combination of dopamine and pectin solutions. It presents the maximum adhesion force and detachment stress results from treated and untreated wood samples.

Explanations

Beech Wood & Sample Preparation

The beech wood samples were placed in a sample holder and underwent treatments with dopamine and pectin solutions.

Treatments

Dopamine Solution: Known for its adhesive properties.
Pectin Solution: A polysaccharide that can influence adhesion.

Experimental Results

Graph 1 (Max. Adhesion Force):

- Delignified samples treated with dopamine and pectin show significantly higher adhesion forces compared to samples treated with only dopamine or only pectin or no treatment at all.

- *Max Adhesion Force (N)*:
  - Delignified only: 0.1 N
  - Only dopamine: 0.1 N
  - Only pectin: 0.5 N
  - Dopamine + pectin: 2.3 N

Graph 2 (Detachment Stress):

- Samples show increased detachment stress at 25°C and 45°C, particularly for rough surfaces.
- *Detachment Stress (N/mm2̂)*:
  - Smooth: Lower values (0.02-0.04 N/mm^2)
  - Rough: Higher values (0.07-0.1 N/mm^2)

Notes:

- Dopamine and pectin are used together to significantly improve the adhesion properties of untreated beech wood.
- A higher detachment stress on rough surfaces indicates better adhesion characteristics.

Summary and Explanation of Slide 36 on BIOFOULING AND BIOGLUES

Summary

This slide illustrates various examples of biological adhesives derived from glycoproteins and their applications.

Explanations

Concepts and Terms

Biological Adhesives: Sticky substances produced by living organisms for attachment, protection, and other purposes
Glycoproteins: Molecules consisting of a protein and a carbohydrate (sugar) component, which can function as adhesives

Examples from Nature

Glycoproteins are sourced from organisms such as ivy, snails, spiders, hagfish, and jellyfish.

Applications Mentioned

Collagen-derived scaffold with ivy nanoparticles

- Used for creating biocompatible scaffolds in tissue engineering and regenerative medicine.

Snail slime-coated gold nanoparticles

- Employed in drug delivery systems due to their adhesive properties and biocompatibility.

Mucin/keratin scaffolds (from hagfish)

- Applied in wound healing and medical dressings for their moisture-retaining and protective qualities.

Electrospun (glyco-) protein scaffold of jellyfish mucin

- Utilized in advanced filtration systems and as scaffolding for cell growth due to their structural integrity and adhesive nature.

Notes

- The slide shows how biomolecules like glycoproteins are modified to create effective adhesives.
- These adhesives have diverse applications including medical, industrial, and environmental uses due to their biocompatibility and strength.

Summary and Explanation of Slide 37 on BIOFOULING AND BIOGLUES

Summary

This slide explains the stickiness of spider webs, focusing on the composition of the silk fibers and the coating that makes them adhesive.

Explanations

Concepts and Terms:

Spider Web Structure: *Web Frame Silk Fibers*: These are the strong fibers that create the basic structure and support of the web, where the spider walks. *Catching Silk Fibers*: These are the sticky fibers designed to capture prey.
Adhesive Coating: The catching silk fibers are coated with an aqueous (water-based) solution. This solution consists of (glyco)proteins and salts, which function as glue to make the web sticky.

Diagrams and Data

The diagram shows the spider's various silk-producing glands and the types of silk they produce, each serving different purposes within the web structure.

- *Aggregate Gland*: Produces the glue-like substance.
- *Major and Minor Ampullate Glands*: Produce frame silk and dragline silk.

- *Flagelliform Gland*: Produces the stretchy fibers for the capture spiral.
- Other glands contribute to various silk types used for different parts of the web and reproduction processes.

Notes:

- The slide highlights the natural biomaterial properties of spider silk and its practical application in understanding bioadhesives and potential mimicking for human technology.
- Understanding these principles can aid in the study of biofouling and the development of new bioglues inspired by natural adhesives like those found in spider webs.

Summary and Explanation of Slide 38 on BIOFOULING AND BIOGLUES

Summary

The slide discusses how humidity affects the stickiness of spider glue, including adhesion and viscosity changes across different spider species.

Explanations

Concepts and Terms

Spider Glue Components:
Fiber: Structural part of the spider silk.
Granule: Small spherical substances in the glue.
Glue: The sticky substance that aids in trapping prey.

Humidity Effect on Stickiness:
Increased humidity leads to higher adhesion and viscosity of spider glue.
The images illustrate the stretching and thinning of spider glue under different humidity conditions.

Viscosity and Adhesion Data:
Adhesion (% RH - Relative Humidity): The effectiveness of the glue at maximum humidity is presented in percentages for different species.
Viscosity (cP - Centipoise): Measure of glue's resistance to deformation, shown as viscosity and its range.

Spider Species Data:
Argiope: 30% adhesion, $\sim$7 x 10^5 cP viscosity.
Larinioides: 50% adhesion, $\sim$1 x 10^5 cP viscosity.
Verrucosa: 50% adhesion, $\sim$8 x 10^5 cP viscosity.

Neoscona: 70% adhesion, ~6 x 10^4 cP viscosity.
Tetragnatha: 90% adhesion, viscosity not specified.

Diagrams and Data

Diagrams Showing Spider Glue

- The left three images show glue stretching/thinning under humidity variations.

Adhesion and Viscosity Graphs

- Illustrate how bulk dissipation (resistance to deformation) and spreading (surface contact area) affect adhesion and viscosity.

Notes

- *Humidity Tuning*: The ability to adjust adhesion and viscosity based on humidity allows spiders to optimize their webs for different environmental conditions.
- *Application Insight*: Understanding these mechanisms in spider glue can inspire the design of synthetic adhesives responsive to environmental factors.

Summary and Explanation of Slide 39 on BIOFOULING AND BIOGLUES

Summary

This slide discusses the issue with conventional medical adhesive tapes which can damage sensitive skin, and introduces the concept of medical tape with a sacrificial glue layer to mitigate this problem.

Explanations

Concepts and Terms

Sensitive Skin Damage: The slide shows how conventional medical adhesive tapes, such as band-aids, can damage sensitive skin (e.g., of babies) upon removal.
Sacrificial Glue Layer: This concept is suggested as a solution to prevent skin damage. The idea is that the outer layer of adhesive can be peeled away without affecting the sensitive skin.

Diagrams and Data

Image A

- Shows a child's skin damaged by adhesive tape.

Central Diagram

- Illustrates how conventional medical tape works, showing the attachment to the sensitive skin and the resulting damage after removal.

- Includes a depiction of residual adhesive left on the skin.

Images C (i) and C (ii)

- Demonstrate the effect of different tapes when removed from paper.
- Compare paper tape, plastic tape, and quick-release tape, showing how the latter leaves less residue and is less likely to cause damage.

Notes:

- *Practical Application*: The inclusion of a sacrificial layer in medical tapes could significantly reduce skin damage, particularly beneficial for infants and individuals with sensitive skin.
- *Testing on Paper*: The demonstration with paper illustrates the practical differences in adhesive residue and damage, providing a clear visual comparison for the effectiveness of different tapes.
- This slide is relevant as it brings to light a critical problem in medical practice and proposes a potential advanced solution using bioglues.

Summary and Explanation of Slide 40 on BIOFOULING AND BIOGLUES

Summary

The slide discusses a novel medical tape design with a sacrificial glue layer, which leaves the adhesive on the skin when removed.

Explanations

Relevant Concepts

Two-Layer Tape Design: The tape consists of a backing intermediate layer and an adhesive layer. The innovative design enables the adhesive part to stay on the skin after removal.
Medical Tape Usage: The tape is quick-release and designed to be used on sensitive skin.
Sacrificial Glue Mechanism: When removed, the tape leaves behind a layer of adhesive on the skin which can be rolled off with a finger, minimizing skin irritation.

Diagrams and Data

Left Image

- Shows the initial state with the quick-release medical tape affixed to sensitive skin.
- The components include a coated backing/adhesive interface and a skin/adhesive interface.

Middle Image

- Illustrates the tape after removal.
- The skin remains intact while the adhesive layer stays on the skin.

Right Image

- Depicts a finger easily rolling off the residual adhesive from the skin.

Notes:

- This innovative approach offers a potential bioglue solution for medical applications that require minimized skin damage and ease of adhesive removal.

Summary and Explanation of Slide 41 on BIOFOULING AND BIOGLUES

Summary

The slide discusses the concept of using talcum powder to dry and easily remove the residual adhesive layer on medical tape.

Explanation

Concept

Medical Tape with Sacrificial Glue Layer: The slide shows a strategy for dealing with the residual adhesive on medical tape.
Talcum Powder Application: Applying talcum powder to the adhesive layer helps to dry it out.

Mechanism

The powder absorbs moisture from the adhesive, which neutralizes its stickiness, making it easier to remove the tape without leaving residue.

Diagram Explanation

Left Image

- Shows tape with residual adhesive.

Middle Image

- Represents the application of talcum powder.

Right Image

- Shows the tape with talcum powder mixed into the residual adhesive.

Graph Explanation

Tensile Fracture Strength

- *Adhesive*: Shows a higher tensile fracture strength.
- *Adhesive + Talcum Powder*: The tensile fracture strength significantly decreases, indicating that the adhesive properties are reduced when talcum powder is applied.

Notes

- The use of talcum powder is a practical tip for handling adhesive residues, highlighting its role in bioglues and biofouling management.

Summary and Explanation of Slide 42 on BIOFOULING AND BIOGLUES

Summary

The slide illustrates the stages of bacterial adhesion and biofilm formation, emphasizing the difficulty of combatting biofilms after they have formed.

Explanations

Concepts and Terms

Biofilm Formation Stages:
Stage 1: Initial Attachment: Bacteria adhere loosely to a surface.
Stage 2: Irreversible Attachment: Bacteria adhere more permanently, making it harder to remove them.
Stage 3: Maturation I: Bacterial colonies begin to grow and form microcolonies.
Stage 4: Maturation II: Further growth leads to mature biofilms with complex structures.
Stage 5: Dispersion: Parts of the biofilm disperse to form new bacterial colonies.

Biofilms:
Biofilms are structured communities of bacteria encased in a self-produced polymeric matrix that adheres to surfaces.
Once established, biofilms are resilient and difficult to eradicate, posing challenges in medical, industrial, and environmental contexts.

Diagrams and Data

Biofilm Development:

- The diagram shows a visual representation of the five stages of biofilm development of *Pseudomonas aeruginosa*.
- Each stage is accompanied by photomicrographs showing the physical state of the bacteria at the corresponding stage.

Notes

- *Prevention*: Preventing the initial bacterial adhesion is crucial to stopping biofilm formation.
- Understanding biofilm lifecycle stages can help in developing strategies to prevent and control biofilm-associated problems.

Summary and Explanation of Slide 43 on BIOFOULING AND BIOGLUES

Summary

This slide presents various anti-biofouling strategies employed to prevent the attachment and growth of bio-organisms on surfaces.

Explanations

Concepts and Terms

Non-wetting surfaces: These surfaces are designed to repel water, preventing the attachment of bio-organisms. An example image shows water droplets on a hydrophobic surface. **Anti-adhesive surfaces:** These surfaces inhibit the adhesion of microorganisms. The diagram illustrates live bacteria failing to adhere due to specific surface treatments or coatings. **Toxic surfaces:** These surfaces actively kill bio-organisms that come into contact with them. The illustration shows two types:

- *Leachable surface:* Releases toxic substances that kill bacteria.
- *Contact-kill surface:* Directly kills bacteria on contact.

Shedding/sloughing: This involves surfaces that can shed or slough off to remove any attached organisms. The image shows an example resembling a marine organism, which naturally sloughs off its surface layer.

Notes:

- Non-wetting and anti-adhesive surfaces focus on preventing initial attachment of bio-organisms.
- Toxic surfaces and shedding mechanisms are used to continually eliminate or remove bio-organisms to maintain a clean surface.

Summary and Explanation of Slide 44 on BIOFOULING AND BIOGLUES

Summary

This slide presents a table outlining various medical materials and their mechanisms for preventing biofouling. The listed materials include metal, hydroxyapatite, antiseptic, antibodies, PEG (polyethylene glycol), oligoethylene glycol, zwitterionic polymers, and fluoropolymer/fluorosilane.

Explanations

Concepts and Terms

Biofouling: The accumulation of microorganisms, plants, algae, or animals on wetted surfaces, leading to a range of issues including infection and device failure in medical contexts.
Mechanisms Listed:

- *Metal:* Utilizes toxic silver or zinc-coated surfaces to deter biofouling.
- *Hydroxyapatite:* Applies toxic coatings, particularly for osteosynthesis (bone synthesis) applications.
- *Antiseptic:* Uses toxic coatings with agents like chlorhexidine and chloroxylenol to prevent fouling.
- *Antibodies:* Implements toxic coatings impregnated with antibiotics to combat microbial adhesion.

- *PEG (Polyethylene Glycol):* Employs SAMS (Self-Assembled Monolayers) with hydrophilic surfaces to prevent protein adsorption and adhesion.
- *Oligoethylene Glycol:* Also uses SAMS with hydrophilic surfaces to deter fibrinogen adsorption (a key protein in blood clot formation).
- *Zwitterionic Polymers:* Creates surfaces that are hydrophilic, thus deterring protein adsorption and reducing bioadhesion.
- *Fluoropolymer and Fluorosilane:* Enhances biocompatibility of implantable devices by reducing protein adsorption.

Notes:

- **Self-Assembled Monolayers (SAMS):** Organized layers of molecules that spontaneously form on surfaces, providing a method to control surface properties at the molecular level.
- **Biocompatibility:** Refers to how well a material is accepted by the body without inducing an adverse reaction. Materials with higher biocompatibility are preferable for medical implants.
- **Hydrophilic Surface:** A surface that has an affinity for water, usually resulting in reduced protein and microbial adhesion due to the formation of a hydration layer.

Summary and Explanation of Slide 45 on BIOFOULING AND BIOGLUES

Summary

This slide lists various types of marine/industrial biofouling prevention methods along with their mechanisms.

Explanations

Concepts and Terms

Metal Coating: Involves using toxic copper or silver-coated surfaces to prevent biofouling.
Silicone Elastomer: Uses materials with low surface energy to promote low bioadhesion.
Self-Polishing Copolymer: Paint containing copper, tin, zinc, or biocides that release during vessel movement to prevent fouling.
Hydrogels: Hydrophilic surfaces that confuse biofouling organisms.
Biological: Utilizes natural deterrents like bacteria, algae, and invertebrates to prevent fouling.
Enzymes: Reduces bioadhesion and lyse bacteria.
Hormones: Promotes premature metamorphosis of larva.
Short Fibers: Uses fibers or spikes to confuse biofouling organisms.
Conductive Paint: Involves electrochemical disinfection processes.
Organo-Metallic: Incorporates toxic flexible metal surfaces.
Plastic Film: Uses disposable films that are removed along with the fouling.
Photoactive Film: Self-cleaning films utilizing UV or visible radiation.
Cayenne Pepper: Uses pepper in silicone grease as a deterrent.

Notes:

- This slide provides an overview of the various methods and materials used in preventing biofouling in marine/industrial settings, highlighting the diversity of approaches from chemical coatings to biological and physical barriers.

Summary and Explanation of Slide 46 on BIOFOULING AND BIOGLUES

Summary

The slide discusses anti-biofouling strategies focusing on non-wetting surfaces, with examples from nature such as pigeon feathers, water ferns, broccoli, and butterflies.

Explanations

Concepts and Terms

Anti-biofouling strategies: These are methods to prevent the accumulation of unwanted biological material on surfaces, which is crucial in various industries like marine transportation and healthcare.
Non-wetting surfaces: These surfaces repel water, which prevents organisms from attaching and forming biofilms. Non-wetting properties are often found in certain natural surfaces.

Examples Provided

Pigeon (feathers)

- Pigeon feathers have microstructures that make them non-wetting, preventing water and debris from sticking.

Water Fern

- These aquatic plants have surfaces that repel water, preventing the attachment of other aquatic organisms.

Broccoli

- The waxy surface of broccoli repels water droplets, which can help prevent the attachment of potential pathogens.

Butterflies

- Butterfly wings have microstructures that repel water and dirt, which also helps to maintain their flying ability by reducing weight.

Notes:

- Understanding these natural examples can inspire the development of synthetic materials designed to mimic these non-wetting properties for industrial applications.

Summary and Explanation of Slide 47 on BIOFOULING AND BIOGLUES

Summary

The slide explains the effect of surface properties (*hydrophilic vs. hydrophobic*) on the settlement of micro-organisms and the efficiency of self-cleaning by water droplets.

Explanation of Concepts and Terms

Micro-organism Settlement

Micro-organisms tend to settle on surfaces where they can attach firmly.
Hydrophilic surfaces retain a wetted surface, providing a permanent habitat for micro-organisms, making them prone to biofouling.
Hydrophobic surfaces have dry surfaces that evaporate quickly, providing fewer opportunities for micro-organisms to attach, hence less prone to biofouling.

Self-Cleaning Efficiency

Hydrophilic surfaces: Water droplets on these surfaces lead to biofouling, as valleys and dislodged material trap residues.
Hydrophobic surfaces: These tend to be more efficient in self-cleaning. Water droplets roll off, carrying away attached particles, thus resisting biofouling.

Examples

Hydrophilic

- Elephant ear (*Alocasia odora*)
- Micro-textured shark skin (specifically *C. galapagensis*) – retains water and remains wet

Hydrophobic

- Water fern (*Regnellidium diphyllum*)
- Superhydrophobic surfaces with nanocolumns on insect wings (*Cicada orni*) – shows high resistance to biofouling and efficient self-cleaning

Notes

- **Hydrophilic**: Attracts water, stays wet, more biofouling
- **Hydrophobic**: Repels water, stays dry, less biofouling
- **Biofouling**: Accumulation of organisms on surfaces, which is undesirable in various applications (e.g., ship hulls, underwater sensors)
- **Self-Cleaning Surfaces**: Surfaces that can stay clean with minimal external intervention

Understanding these concepts is crucial for designing surfaces in various industrial and biological applications to either promote or resist the accumulation of micro-organisms and facilitate easy cleaning.

Summary and Explanation of Slide 48 on BIOFOULING AND BIOGLUES

Summary

The slide discusses anti-biofouling strategies, specifically focusing on anti-adhesive surfaces derived from natural sources such as seaweed, eel grass, mammalian tears, sharks, and dolphins.

Explanations

Concepts and Terms

Anti-biofouling: Refers to the prevention of unwanted accumulation of microorganisms, plants, algae, and animals on wetted surfaces.
Anti-adhesive surfaces: These surfaces are designed to prevent organisms, particularly bacteria, from adhering to them.

Diagrams and Data

Relevant Examples from the Slide

- *Seaweed and Eel Grass*: Both are marine plants that have surfaces which naturally resist the adhesion of organisms.
- *Mammalian Tears*: Tears contain natural antimicrobial properties that help keep the eye surface clear of microbial adherence.
- *Shark Skin*: The texture of shark skin (dermal denticles) prevents microbes and small organisms from attaching to it.

- *Dolphin Skin*: Dolphin skin has properties that resist biofouling, likely due to its smooth, renewing surface.

Notes:

- Anti-adhesive surface strategies focus on mimicking these natural examples to develop synthetic materials and coatings for various applications, particularly in the marine industry and biomedical devices, to prevent biofouling.

Summary and Explanation of Slide 49 on BIOFOULING AND BIOGLUES

Summary

The slide discusses the microscopic structure of shark skin and its resistance to biofouling.

Explanations

Microscopic Structure

Shark skin is composed of microscopic scales, known as dermal denticles, which are triangular and range from 200-500 micrometers in length. These scales have fine ridges that are regularly spaced (30-100 micrometers apart) and aligned along the body axis of the shark.

Anti-Biofouling Property

This unique structure helps sharks resist colonization by marine microorganisms, mussels, and barnacles. The scales reduce drag, improving liquid flow across the skin, which helps in preventing biofouling.

Notes

- The images on the slide are electron microscope images showing the detailed structure of the shark skin scales.
- The fine ridges on the scales help in minimizing the surface area that microorganisms can attach to, aiding in biofouling prevention.

Summary and Explanation of Slide 50 on BIOFOULING AND BIOGLUES

Summary

The slide explains the process of replicating shark skin using PDMS (Polydimethylsiloxane) molding, which can be used to recreate the unique topography of shark skin.

Explanation

Steps to Replicate Shark Skin:

Step 1: Molding of PDMS
Sharkskin: The original shark skin is used as a template.
Mold of PDMS: PDMS is poured over the shark skin.
Degassing & Solidifying: The PDMS is degassed (removing bubbles) and allowed to solidify.
Flexible Demolding: The solidified PDMS mold is removed from the shark skin.

Step 2: Large-Scale Swelling of PDMS
Swelling of PDMS Mold: The PDMS mold is exposed to a gaseous n-hexane atmosphere, which causes it to swell. The degree of swelling can be controlled over time.

Step 3: Formation of Amplified Sharkskin
Epoxide Resin: Epoxide resin is applied to the swollen PDMS mold.
Degassing & Solidifying: The resin is degassed and solidified to form the final replica.
Flexible Demolding: The amplified sharkskin replica is then removed from the mold.

Images:

(a) A real shark skin

- Shows the natural texture of shark skin.

(b) PDMS negative replica

- Illustrates the replicated mold formed by the PDMS.

(c) Shark-skin replica

- The final amplified replica that mimics the shark skin's topography.

Notes

- *PDMS (Polydimethylsiloxane):* A silicon-based organic polymer known for its flexibility, transparency, and moldability.
- *Epoxide Resin:* A type of polymer used for casting and molding applications due to its excellent adhesion and strength.
- *Swelling Process:* Adjusting the swelling of the PDMS mold is crucial to replicating the desired texture accurately.

This replication process is significant in biomimicry and could be used to develop materials and surfaces with similar functionality to natural shark skin, such as reduced drag in water or anti-fouling properties.

Summary and Explanation of Slide 51 on BIOFOULING AND BIOGLUES

Summary

The slide discusses the colonization of replicated shark skin PDMS (Polydimethylsiloxane) by algae after a 70-day incubation in a river, comparing it to flat PDMS.

Explanations

Concepts and Terms

PDMS (Polydimethylsiloxane): A silicon-based organic polymer known for its hydrophobic properties, used here in flat form and as a replication of shark skin texture.
Algae Colonization: The process by which algae settle and grow on surfaces which can indicate the material's resistance to biofouling.
Hydrophobic Angle: The contact angle of water on a surface, indicative of its hydrophobicity. The flat PDMS showed a contact angle of 101°, whereas the "shark" PDMS had a higher contact angle of 119°, indicating greater hydrophobicity.

Diagrams and Data

Images (C and D)

- *Top Row - Flat PDMS*: Shows surface images under SEM directly after incubation and after additional washing. It illustrates the extent of algae colonization and its removal efficiency.

- *Bottom Row - "Shark" PDMS*: Shows textured PDMS with replicated shark skin structure. Likewise, images are taken directly after incubation and after washing, showcasing reduced biofouling.

Notes:

- The increased hydrophobicity and surface texture of "shark" PDMS likely contribute to its effectiveness in reducing biofouling by making it more difficult for algae to adhere and grow. - This slide illustrates biofouling resistance mechanisms through surface design and hydrophobic properties, relevant to material sciences and biofouling mitigation strategies.

Summary and Explanation of Slide 52 on BIOFOULING AND BIOGLUES

Summary

This slide discusses Sharklet technology, which involves micropatterned acryl surfaces that mimic the rough topography of shark skin to reduce bacterial adhesion.

Explanations

Concepts and Terms

Sharklet Technology: Refers to a surface technology that replicates the micropatterns found on shark skin
Micropatterned Acryl Surfaces: These surfaces are engineered to imitate the textured surface of sharkskin, which helps in reducing bacterial adhesion
Bacterial Adhesion: The process by which bacteria attach to surfaces. The slide illustrates a significant reduction (by 2 orders of magnitude) in bacterial adhesion on these patterned surfaces
Bacterial Strains:

- *Staphylococcus aureus (MSSA):* A common strain of bacteria that can cause infections
- *Methicillin-resistant Staphylococcus aureus (MRSA):* A strain of Staphylococcus aureus that is resistant to several antibiotics

Diagrams and Data

Images

- One of the images shows the natural pattern of Galapagos shark skin
- The other shows the artificial micropattern created by Sharklet technology

Graph

- The bar graph compares bacterial adhesion on smooth and micro-patterned surfaces
- MSSA and MRSA adhesion on smooth surfaces is shown to be significantly higher compared to the micro-patterned surfaces, with bacterial adhesion reduced by 99% and 98%, respectively

Notes:

- The patterns on Sharklet technology surfaces significantly reduce the ability of bacteria to adhere, which can be beneficial in preventing infections, especially those caused by resistant strains like MRSA

Summary and Explanation of Slide 54 on BIOFOULING AND BIOGLUES

Summary

The slide demonstrates how free sugars promote biofilm formation by the bacterium *Streptococcus mutans* on different surfaces (glass and hydroxyapatite/enamel). It compares the effects of glucose and sucrose.

Explanations

Graphs

A and C: Attached Bacteria (CFU/μL) on Glass (A) and Hydroxyapatite/Enamel (C):

- Measure the number of bacteria attached to the surfaces over time (20, 40, and 60 minutes).
- Comparison between two media: Medium + Glucose (Blue bars) and Medium + Sucrose (Black bars).
- Higher attachment rates are observed with sucrose compared to glucose.

B and D: Biofilm Bacteria/Total Bacteria (%) on Glass (B) and Hydroxyapatite/Enamel (D):

- Show the percentage of bacteria forming biofilms out of the total number of bacteria over time (6, 18, and 24 hours).
- Sucrose enhances biofilm formation more significantly than glucose over time.

Terms

CFU (Colony-Forming Units): Represents the number of viable bacteria cells
Biofilm: A structured community of bacteria adhered to a surface and enclosed in a self-produced polymeric matrix

Notes

- The asterisk (*) indicates a statistically significant difference between the groups being compared
- Sucrose significantly enhances the ability of *Streptococcus mutans* to form biofilms compared to glucose on both glass and hydroxyapatite surfaces. This can be critical in understanding dental plaque formation and developing preventive strategies
- This slide effectively illustrates the role of different sugars in biofilm formation by *Streptococcus mutans* and can be particularly relevant for understanding dental caries development.

Summary and Explanation of Slide 55 on BIOFOULING AND BIOGLUES

Summary

The slide illustrates that salivary mucins reduce biofilm formation by the bacterium *Streptococcus mutans* on two different surfaces: glass and hydroxyapatite (enamel). Four graphs (A, B, C, D) compare biofilm formation and bacterial attachment over time in different media.

Explanations

Concepts and Terms

Graphs A and C: Bacterial attachment over time
Surface: Glass (A) and Hydroxyapatite (C)
Variables: Bacterial attachment over 20, 40, and 60 minutes.
Legend:

- White bar: SMedium + Mucins
- Grey bar: SMedium + Methylcellulose
- Black bar: SMedium (Control)

Observation: The white bars (containing mucins) consistently show significantly lower bacterial attachment compared to the other conditions, indicating that mucins inhibit bacterial attachment. The asterisks (*) denote significant differences.

Graphs B and D: Biofilm formation over time
Surface: Glass (B) and Hydroxyapatite (D)

Variables: Biofilm formation over 6, 18, and 24 hours.
Legend: Same as above.
Observation: The white bars (containing mucins) show significantly lower biofilm formation compared to the other conditions. This suggests that mucins not only reduce initial bacterial attachment but also inhibit subsequent biofilm development. Again, the asterisks (*) denote significant differences.

Notes:

- **Salivary Mucins:** These are glycoproteins found in saliva that can prevent the adhesion of bacteria to surfaces, crucial for dental health.
- *Streptococcus mutans:* A common bacterium in the mouth associated with tooth decay, making it relevant in studies of biofilm formation and dental plaque.
- **Hydroxyapatite:** A component of tooth enamel, used here to mimic natural conditions in biofilm studies.

Summary and Explanation of Slide 56 on BIOFOULING AND BIOGLUES

Summary

This slide discusses the hypothesis that mucins prevent biofilm formation by *S. mutans* on tooth surfaces.

Explanations

Concepts and Terms

Mucins: Glycoproteins found in mucus that play a role in preventing the attachment and growth of bacteria.
S. mutans: *Streptococcus mutans*, a significant bacterium involved in the formation of dental biofilms and tooth decay.
Biofilm Formation: The accumulation of bacteria on surfaces, leading to the creation of microbial communities that are often more resistant to external factors.

Explanation

Hypothesis: *S. mutans* uses sucrose to produce sticky extracellular polysaccharides that aid in biofilm formation on the tooth surface.
The presence of mucins can decrease the attachment of *S. mutans* and subsequent biofilm formation. This is because mucins help keep *S. mutans* in a planktonic (free-floating) state instead of attaching to surfaces.

Diagrams and Data

Diagram (A and B)

- **Diagram A:** Depicts mucins preventing *S. mutans* from adhering to the tooth surface.
- **Diagram B:** Illustrates the typical attachment of *S. mutans* forming a biofilm on a tooth surface without the presence of mucins.

Notes:

- Understanding how mucins prevent biofilm formation can inform strategies for preventing dental plaque and cavities.

Summary and Explanation of Slide 57 on BIOFOULING AND BIOGLUES

Summary

The slide discusses the effect of tear film components on bacterial adhesion to different types of contact lenses (CLs). Data from lab tests reveal that tear films adsorbed onto contact lenses can reduce bacterial adhesion.

Explanations

Concepts and Terms

Contact Lens Types: CL A and CL B with and without adsorbed tear film.
P. aeruginosa (hydrophobic) and S. aureus (hydrophilic): Types of bacteria studied.
j_0: Initial deposition rate (cm^2/s)—the rate at which bacteria initially adhere to the contact lens.
n_2^h: Number of adherent bacteria after 2 hours.
d_0%: Percentage of detached bacteria after rinsing—indicating how many bacteria are removed after a rinse.

Diagrams and Data

CL A vs. CL B

- Both types of lenses show a significant reduction in bacterial adhesion when adsorbed tear film is present.

P. aeruginosa (hydrophobic)

- Reduction from 2053 to 624 for CL A.
- Reduction from 2184 to 895 for CL B in terms of initial deposition rate (j_0).

S. aureus (hydrophilic)

- Reduction from 239 to 322 for CL A.
- Reduction from 164 to 391 for CL B in terms of initial deposition rate (j_0), showing similar trends.

Effectiveness of Detachment After Rinsing

- Higher percentages (d_0%) for S. aureus indicate more effective detachment after rinsing when tear film is present, except for CL B, where it is decreased.

Notes

- *Inquiry:* The slide poses the question: ”What part of the tear fluid could be responsible?” encouraging further investigation into which component of tear film inhibits bacterial adhesion.
- *Study Reference:* The data is sourced from Bruinsma et al. in their 2001 Biomaterials publication.

Summary and Explanation of Slide 58 on BIOFOULING AND BIOGLUES

Summary

This slide discusses anti-bacterial mucin coatings that reduce bacterial adhesion by turning hydrophobic surfaces hydrophilic. The data reveals that salivary mucin coatings significantly reduce the adhesion of *Staphylococcus aureus* and *Staphylococcus epidermidis* on various polymer surfaces.

Explanations

Concepts and Terms

Mucin Coatings: Mucins are glycoproteins from saliva that, when passively adsorbed onto surfaces, can turn hydrophobic surfaces into hydrophilic ones.
Hydrophobic vs. Hydrophilic: Hydrophobic surfaces repel water, whereas hydrophilic surfaces attract water.
Adhesion of Bacteria: The study measures the number of bacteria (*Staphylococcus aureus* and *Staphylococcus epidermidis*) adhered to surfaces.

Diagrams and Data

Contact Angles

- **Before Coating**: High contact angles signify hydrophobic surfaces (e.g., Polystyrene: $115 \pm 2.9°$).
- **After Coating**: Contact angles drop drastically, indicating increased hydrophilicity (e.g., Polystyrene: $8.5 \pm 0.41°$).

Reduction in Bacterial Adhesion

- **PMMA (Polymethyl methacrylate)**: Significant reduction in bacterial numbers for coated surfaces.
- **PU (Polyurethane)**, **PS (Polystyrene)**, **Silicone Gel**: All show reduced bacteria adhesion post mucin coating.

Notes:

- **Salivary Mucin's Role**: Salivary mucins (BSM) effectively decrease bacterial attachment, potentially useful for medical implants and devices.
- *Data Source*: Shi et al., *Colloids and Surfaces* (2000), provides experimental evidence for the anti-bacterial properties of mucin coatings.

These findings can be crucial for developing anti-biofouling materials in medical and environmental applications.

Summary and Explanation of Slide 59 on BIOFOULING AND BIOGLUES

Summary

The slide discusses the efficacy of anti-bacterial mucin coatings in reducing bacterial adhesion. The glycan groups in these mucins are crucial for their anti-bacterial properties.

Explanations

Concepts and Terms

Mucins: These are glycoproteins present in mucus that can prevent bacterial adhesion.
Gastric Mucins: Derived from the stomach.
Submaxillary Mucins: Derived from the salivary glands.
Anti-bacterial Properties: The ability of mucins to prevent bacteria from sticking to surfaces.
Glycan Groups: Sugar chains present in mucins, essential for their anti-bacterial activity.

Diagrams and Data

Images of Bacterial Adhesion

- Uncoated Polystyrene: High bacterial presence.
- Gastric Mucins and Submaxillary Mucins: Reduced bacterial adhesion in comparison to the uncoated surface.

Graphs

- The bar graphs display bacterial attachment levels of *S. pneumoniae* and *S. aureus* on different surfaces.
- **Left Graph**: Gastric mucins vs. Apo-gastric mucins.
- **Right Graph**: Submaxillary mucins vs. Apo-submaxillary mucins.
- The graphs indicate that native mucins (with glycans) have lower bacterial attachment compared to apo-mucins (without glycans).

Illustration

- Depiction of native mucin coating and its structure vs. apo-mucin coating, highlighting the importance of glycan groups in forming an effective anti-bacterial barrier.

Notes

- Glycan groups play a critical role in the anti-bacterial properties of mucin coatings.
- Apo-mucins (devoid of certain glycan groups) are less effective in bacterial adhesion prevention.

Summary and Explanation of Slide 60 on BIOFOULING AND BIOGLUES

Summary

The slide discusses the use of anti-biofouling biopolymer coatings on Endotracheal Tubes (ETTs). It details the process of creating these coatings and provides examples of various biopolymers used, categorized by their charge properties and molecular weights.

Explanations

Concepts and Terms

Anti-Biofouling Biopolymer Coatings: These are coatings applied to surfaces to prevent the accumulation of biological materials, such as bacteria, on medical devices like ETTs.
ETTs (Endotracheal Tubes): Tubes used in medical procedures to ensure an open airway to the lungs.
Coating Process:

- *Plasma Activation*: Uses plasma to create reactive species on the surface.
- *Silane Pre-coating*: Applies a silane compound to enhance surface reactivity.
- *1st Activation with EDC*: Uses EDC (a carbodiimide crosslinker) to activate carboxyl groups.
- *2nd Activation with NHS*: Uses NHS (N-Hydroxysuccinimide) to stabilize the activated surface for coupling.

- *Final Macromolecule Coupling*: Involves attaching the biopolymer to the activated surface.

Biopolymers and Their Properties:

- *Mucin (MUC)*: High molecular weight glycoprotein (2-3 MDa).
- *Hyaluronic Acid (HA)*: Anionic polysaccharide (1-2 MDa).
- *Lysine Dextran (L-Dex)*: Cationic biopolymer (500 kDa).
- *Polyethylene Glycol (PEG)*: Uncharged polymer (100 kDa).

Notes

- **Anionic, Cationic, and Uncharged**: These terms refer to the electrical charge of the biopolymers, which influences their interactions with surfaces and biological molecules.
- **Molecular Weight (kDa and MDa)**: Indicates the size of the polymer molecules; larger molecules may form thicker, more durable coatings.

Understanding these details can help in appreciating how surface modifications using biopolymers can enhance the performance and safety of medical devices by reducing biofouling.

Summary and Explanation of Slide 61 on BIOFOULING AND BIOGLUES

Summary

The slide discusses the effectiveness of various anti-biofouling biopolymer coatings on Endotracheal Tubes (ETTs). Several bar graphs compare the levels of biofouling and bacterial counts of *S. pyogenes* and *S. aureus* on uncoated and coated surfaces with different biopolymers: MUC (mucin), HA (hyaluronic acid), PEG (polyethylene glycol), and L-Dex (low-density dextran).

Explanation

Graphs c, d, e:

c) Biofouling (%): Measures the percentage of cell biofouling on different coatings.
MUC coating shows significantly lower biofouling compared to other coatings.

d) S. pyogenes Bacteria Count: Compares bacterial count on coatings.
MUC and HA show a significant reduction in bacterial count.

e) S. aureus Bacteria Count: Compares bacterial count on coatings.
MUC shows a substantial reduction, with other coatings also reducing bacterial counts but less effectively.

Graphs f, g:

f) Lipid Covered Area (%): Compares the lipid-covered area on coatings.

- MUC shows a significant reduction in lipid coverage, unlike the other tested coatings, which show similar results to lipids on uncoated surfaces.

g) BSA Covered Area (%): Measures the area covered by BSA (Bovine Serum Albumin) at neutral pH.

- MUC shows significantly reduced BSA coverage indicating higher resistance to fouling compared to other coatings.

Concepts and Terms

Biofouling: Accumulation of microorganisms, plants, algae, or animals on wetted surfaces.
Anti-biofouling Biopolymers: Materials applied to surfaces to reduce or prevent biofouling.
MUC: Mucin, showing high effectiveness in reducing biofouling and bacterial attachment.
HA: Hyaluronic acid, showing moderate anti-biofouling properties.
PEG: Polyethylene glycol, less effective than MUC but still providing some reduction in fouling.
L-Dex: Low-density dextran, generally less effective in preventing biofouling compared to MUC.

Notes

- Cell membranes are mostly anionic, influencing the interaction with different coatings.
- Mucin's unique effectiveness might need further study to understand its unique properties fully.
- BSA (**Bovine Serum Albumin**) is net anionic at neutral pH, affecting its interaction with coatings.

Summary and Explanation of Slide 62 on BIOFOULING AND BIOGLUES

Summary

This slide illustrates the process and effects of biofouling by blood within the cardiovascular system, focusing on the progression from atherosclerosis to thrombus formation and subsequent arterial occlusion.

Explanations

Concepts and Terms

Biofouling by blood: Refers to the clogging or obstruction within blood vessels due to the accumulation of biological materials, like atherosclerotic plaque and thrombus (blood clots).
Atherosclerosis: The initial condition illustrated shows patchy areas of plaque buildup within the arterial walls, which can reduce the vessel's lumen by as much as 30%. This restricts blood flow and can cause complications.
Thrombus Formation: The slide describes how large thrombi can form when the inner lining of the bloodstream is compromised, leading to a blockage in the vessel.
Subsequent Condition: The final part of the diagram shows a thrombus lodged within the vessel, completely occluding blood flow. This can lead to serious cardiovascular events, such as heart attacks or strokes.

Diagrams and Data

Heart Anatomy

- Shows the anterior view of the heart and coronary arteries, highlighting the left anterior descending artery.

Enlarged Sections: Three stages within the left anterior descending artery

- Initial condition with plaque buildup.
- Thrombus formation with a significant blockage.
- Complete occlusion of the artery due to a lodged thrombus.

Notes:

- *Understanding Medical Terms*:
- **Plaque**: It's the buildup of fats, cholesterol, and other substances in and on the artery walls.
- **Thrombus**: A blood clot formed within the vascular system that impedes blood flow.
- **Occlusion**: Blockage or closing of a blood vessel or hollow organ.

- *Implications*: Biofouling from blood clots can lead to critical health conditions, emphasizing the importance of early detection and treatment to prevent severe cardiovascular diseases.

Summary and Explanation of Slide 63 on BIOFOULING AND BIOGLUES

Summary

This slide discusses vascular grafts, particularly in the context of coronary artery bypass surgery. It highlights the necessary characteristics and requirements for an effective vascular graft.

Explanations

Concepts and Terms

Vascular Grafts: These are medical devices used to bypass a constricted coronary artery to ensure proper blood flow, particularly during coronary bypass surgery.

Diagrams and Data

Diagram

- The image shows a human heart with:
  - A constricted coronary artery.
  - A bypass graft placed between the aorta and the coronary artery to allow blood flow.

Key Requirements for a Vascular Graft

- *Adjusted mechanical properties*: The graft must mimic the mechanical properties of the natural artery to withstand the pressure and flow of blood.
- *Resistance to rejection*: The graft material must be biocompatible to prevent the immune system from rejecting it.
- *Anti-thrombogenic (anti-biofouling)*: The graft should prevent blood clot formation and the build-up of biological materials on its surface to ensure longevity and functionality.

Notes

- **Biofouling in Medical Context**: Refers to the accumulation of microorganisms, cells, and other biological materials on medical devices which can lead to complications. In vascular grafts, anti-biofouling properties are critical to prevent thrombosis and ensure the smooth passage of blood.

Summary and Explanation of Slide 64 on BIOFOULING AND BIOGLUES

Summary

The slide reviews three options for vascular grafts, highlighting their pros and cons.

Explanations

Concepts and Terms

Vascular Grafts: Medical devices used to replace or bypass damaged or diseased blood vessels.
Option #1: Autograft - Involves using the patient's own vessels. - Diagram shows graft from leg to heart.
Option #2: Tissue Engineering - Process of growing new tissue from the patient's cells. - Illustrated steps: Biopsy → Cell Culture → Grafting.
Option #3: Synthetic Materials - Engineering grafts with adjustable mechanical properties. - Tunable surface characteristics. - More cost-effective and readily available ("on shelf").

Notes:

- *Autografts* pose challenges such as limited availability of suitable vessels and potential complications at the donor site.
- *Tissue Engineering* is promising but can be complex and time-consuming.
- *Synthetic Materials* offer controllable properties and greater availability but may face issues like biocompatibility and long-term integration.

Summary and Explanation of Slide 65 on BIOFOULING AND BIOGLUES

Summary

The slide discusses vascular grafts and the process of electrospinning to create multi-layer constructs with different properties.

Explanations

Concepts and Terms

Vascular Grafts: These are medical devices used to replace, repair, or bypass sections of blood vessels. The diagram shows various layers of a vessel: *Tunica Externa*, *Tunica Media*, *Tunica Intima*, *Smooth Muscle*, *Endothelium*, *External Elastic Membrane*, and *Internal Elastic Membrane*. The necessity for multi-layer constructs implies different layers must have different properties suitable for their specific function within the graft.
Electrospinning: A technique used to create nanofibers from polymer solutions or melts. The process involves a high-voltage power supply that generates an electric field, drawing a thin jet of polymer towards a grounded collector to create a fiber mat. Two diagrams illustrate the setup for creating fiber mats and cylindrical constructs:

- *Taylor Cone*: The pointed shape of a liquid droplet under the influence of an electric field.
- *Fiber Mat*: The tangled network of fibers collected on a flat surface.

- *Rotating Collector*: Used to produce tubular or cylindrical structures suitable for vascular grafts.

The final image shows a microscopic view of the resulting fibrous structure.

Notes:

- **Importance**: The multi-layer construction is crucial because each layer serves specific functions like providing structural support or biological compatibility.
- **Application in Biofouling and Bioglues**: Understanding the material properties and construction methods helps in designing grafts that minimize biofouling and adhere correctly within the body. “Biofouling” refers to unwanted deposition of biological material on surfaces, while “bioglues” are adhesives derived from biological systems, potentially used in securing grafts.

Summary and Explanation of Slide 66 on BIOFOULING AND BIOGLUES

Summary

The slide discusses the inner layer of vascular grafts made from poly-L-lactide (PLLA).

Explanations

Concepts and Terms

PLLA (Poly-L-lactide): A biodegradable polymer used in medical applications.
Reproducible Electrospun Products: The process of creating fibers through electrospinning results in consistent and reproducible products.
Chemical Modification Method: The chemical structure of PLLA can be modified reliably and consistently.
Biocompatible: The material does not elicit an adverse immune response.
Morphology: The inner layer has a similar structural appearance to native biological matrices.
Fiber Diameter: The diameter of the fibers in the inner layer is around 1.5 μm.
Thickness: The entire inner layer is approximately 50 μm thick.

Notes

- PLLA is often used in tissue engineering due to its favorable properties, including its biocompatibility and biodegradability.

- Electrospinning allows for the creation of nanofibers that can simulate the extracellular matrix, an essential part of tissue scaffolding in medical applications.

Summary and Explanation of Slide 67 on BIOFOULING AND BIOGLUES

Summary

The slide discusses the outer layer of vascular grafts, focusing on its composition, properties, and mechanical performance.

Explanations

Concepts and Terms

Vascular Grafts: Medical devices used to replace or bypass damaged blood vessels.
Outer Layer Composition:

- *PLCG*: Poly(L-lactide-co-caprolactone-co-glycolide)
- *PCL*: Poly(ε-caprolactone)

Properties:

- *Biocompatibility*: The material is compatible with living tissue.
- *Mechanical Properties*: Emphasizes the material's ability to maintain integrity under stress.

Physical Characteristics:

- *Fiber Diameter*: 800 nm
- *Thickness*: Approximately 50 μm

Diagrams and Data

Mechanical Performance Graph

- *Stress-Strain Curve*: Compares the mechanical performance between the graft and natural artery. The black curve represents the artery, and the gray curve represents the graft.
- Indicates similar mechanical performance between the graft and artery, showing the graft's adequacy in mimicking natural arterial properties.

Notes

- The images show the microscopic structure (inner and outer layers) of the vascular graft, highlighting the organized, fibrous composition necessary for optimal mechanical performance.

Summary and Explanation of Slide 68 on BIOFOULING AND BIOGLUES

Summary

The slide discusses the use of mucin coatings on vascular grafts to improve their functionality. It compares four groups of graft treatments and illustrates their respective mucin levels with a bar graph.

Explanations

Concepts and Terms

Vascular Grafts: Medical devices implanted in place of, or in conjunction with, blood vessels.
Mucin Coating: Mucin, a glycoprotein, is used to coat the grafts to potentially reduce fouling and improve compatibility.
Groups Evaluated:

- **Untreated Graft (Untreated)**: Grafts without any surface modification.
- **Covalently Bound Mucin (PEG-MUC)**: Grafts with mucin covalently attached via a di-amino PEG (Polyethylene Glycol) linker.
- **Adsorbed Mucin (MUC)**: Grafts where mucin is adsorbed onto the surface without covalent bonding.
- **PEG Control (PEG)**: Grafts treated only with PEG, which serves as a control for covalent bonding effects.

Diagrams and Data

Graph Explanation

- **Y-axis**: Relative Mucin Level (% Saturated)
- **X-axis**: Different groups (PEG-MUC and MUC), measured under three conditions: Pre-Flow, Post-48h-Flow, and Static Control.
- **Observation**: Mucin levels are highest in the covalently bound mucin group (PEG-MUC) post-48h flow and static control states, illustrating enhanced stability of the mucin coating compared to adsorbed mucin (MUC).

Notes:

- *Importance of Mucin Coating*: Mucin can help in resisting biofouling due to its hydrophilic and lubricative properties.
- *Significance of Data*: Higher retention of mucin in PEG-MUC indicates better long-term stability which is crucial for biomedical applications in vascular grafts.

Summary and Explanation of Slide 69 on BIOFOULING AND BIOGLUES

Summary

This slide discusses platelet adhesion on vascular grafts and how mucins can reduce blood coagulation.

Explanations

Concepts and Terms

Title: The primary focus is on platelet adhesion, which is a crucial factor in the success of vascular grafts.
Graph on the Left: This graph shows the time required for blood coagulation relative to the concentration of various substances (Heparin, MUC, PEG). The data indicates that Heparin significantly increases clotting time compared to untreated samples. Mucins (MUC) and PEG show lower times, with mucins having the lowest coagulation time.
Bar Graph on the Right: This graph quantifies the number of platelets per cm^2 for untreated, PEG, PEG-Muc (combination), and MUC samples. Untreated samples show the highest platelet adhesion. PEG and PEG-MUC show a significant reduction in platelet adhesion, whereas MUC shows a moderate reduction.
Microscopic Images (Bottom): The images demonstrate the surface of vascular grafts under different treatments:

- *Untreated*: Shows a high density of platelets (black arrows).
- *PEG and PEG-MUC*: Show reduced platelet adhesion.

- *MUC*: Shows some platelet adhesion, but it is less than untreated.

Diagrams and Data

Graph on the Left

- The graph illustrates the clotting time for different substances.
- Heparin shows the highest clotting time.
- Mucins (MUC) exhibit the lowest coagulation time among the substances.

Bar Graph on the Right

- The bar graph quantifies the platelet adhesion per cm^2.
- Untreated samples have the highest platelet adhesion.
- PEG and PEG-MUC reduce platelet adhesion significantly.
- MUC also reduces platelet adhesion, though not as much as PEG and PEG-MUC.

Notes

- **Mucins**: These are glycoproteins which affect blood coagulation and platelet adhesion, an essential aspect of improving the biocompatibility of vascular grafts.
- **PEG (Polyethylene Glycol)**: Used to reduce protein adsorption and cell adhesion on surfaces. When combined with mucins, this can further improve the biocompatibility and functionality of vascular grafts.

Summary and Explanation of Slide 70 on BIOFOULING AND BIOGLUES

Summary

The slide presents a study evaluating the efficacy of vascular grafts treated with various substances by testing them *in vivo* (in a live animal model).

Explanations

Concepts and Terms

Vascular Grafts: These are used to replace or repair blood vessels. The slide mentions untreated grafts, PEG (Polyethylene Glycol), PEG-MUC (PEG-mucoprotein conjugate), and MUC (Mucoprotein)
In Vivo Testing: This test is conducted using a live rat model over a period of one month
Patency Test: This test evaluates the openness of the vascular grafts, which includes:

- **Re-distension of forcibly collapsed distal CCA (Common Carotid Artery)**
- **Doppler Ultrasound**: A technique used to measure blood flow and patency non-invasively

Diagrams and Data

The schematic shows the process flow of testing the vascular grafts in rats and conducting a patency test after one month.

- A bar graph is also provided to display the number of patent grafts out of 8 for each treatment type.
- PEG-MUC treated grafts show the highest patency rate.

Notes

- This study highlights the importance of biocompatibility and functional longevity of vascular grafts
- PEG-MUC treatment appears to outperform other treatment types in maintaining graft patency

Summary and Explanation of Slide 71 on BIOFOULING AND BIOGLUES

Summary

This slide discusses anti-biofouling strategies focusing on **toxic surfaces** and includes illustrations and images that present examples of organisms and mechanisms relevant to the strategies.

Explanations

Concepts and Terms

Toxic Surfaces: This type of surface poses a hostile environment to microorganisms, either through release or contact mechanisms
Leachable Surface: This type of surface releases toxic agents that kill bacteria upon contact. The diagram indicates that bacteria die after coming into contact with substances leached from the surface.
Contact-Kill Surface: This surface directly kills bacteria when they come into contact with it. The diagram shows bacteria contacting the surface and subsequently dying.

Diagrams and Data

Examples of Natural Anti-Biofouling Surfaces

- *Gecko*: Known for its ability to repel microorganisms due to its skin structure.

- *Dragonfly*: The wings of a dragonfly possess nanopillars that can puncture bacterial cells upon contact, effectively killing them.
- *Cicada*: Similar to the dragonfly, cicada wings have micro/nano structures that act as anti-biofouling surfaces.
- *Streptomyces (Bacteria)*: A genus of actinobacteria known to produce antibiotics which can be used in forming leachable toxic surfaces.

Notes:

- The focus on **toxic surfaces** relates to their practical applications in preventing biofouling, which is the undesirable accumulation of microorganisms on surfaces.
- Understanding the natural models helps in designing synthetic surfaces for anti-biofouling applications.

Summary and Explanation of Slide 72 on BIOFOULING AND BIOGLUES

Summary

The slide discusses barnacles, showcasing their structure and various surfaces they attach to, such as dead wood and whale skin.

Explanation

Barnacles Structure

The diagram provides a cross-sectional view of a barnacle attached to a substrate.
Key parts labeled include the shell wall, longitudinal canal, tissue, base plate, and cement used for attachment.

Attachment Surfaces

Dead Wood

- Image showing barnacles colonizing dead wood in a coastal area
- Illustrating how they adhere to non-living surfaces

Whale Skin

- Images displaying barnacles attached to whale skin
- Demonstrating their ability to attach to living organisms

Concepts

Biofouling

The attachment of barnacles to surfaces (both living and non-living) is an example of biofouling, where marine organisms adhere to and grow on surfaces.

Bioglues

The cement used by barnacles to attach to substrates can be studied as a natural adhesive, relevant to bioglue research.

Notes

- *Ecological Impact*: Barnacles affect the surfaces they attach to, sometimes causing damage or increased drag for marine organisms such as whales.
- *Research Importance*: Understanding barnacle adhesion can lead to advancements in antifouling technologies and the development of new adhesives.

Summary and Explanation of Slide 73 on BIOFOULING AND BIOGLUES

Summary

This slide discusses the issue of barnacle fouling on ship hulls and propellers, the use of copper paints to prevent this fouling, and the economic impact of fouling.

Explanations

Concepts and Terms

Barnacle Fouling: Barnacles adhere to ship propellers and hulls, causing significant issues.
Copper Paints: Copper paints are applied to ship hulls to prevent barnacle fouling. They are efficient but toxic to other marine life due to their water solubility.
Economic Aspect: Fouling leads to a 20% reduction in propulsion efficiency. This inefficiency results in an additional 16,000 tons of CO_2 emissions and 9 million euros in additional costs per year in Sweden alone.

Diagrams and Data

Illustrative Images

- Images of barnacle-covered propellers and hulls showing the extent of fouling

Performance Comparison

- Graph comparing the performance (thrust T vs power P) of polished propellers and barnacle-covered propellers
- Polished propeller exhibits higher thrust compared to the barnacle-covered propeller at the same power levels, indicating that fouling reduces propeller efficiency

Notes

- **Economic and Environmental Impact:** Reduction in efficiency raises operating costs and environmental damage due to increased fuel consumption and emissions.
- Finding better antifouling solutions that are non-toxic is crucial for sustainable marine operations.

Summary and Explanation of Slide 75 on BIOFOULING AND BIOGLUES

Summary

The slide discusses Avermectins, bactericidal molecules produced by certain soil bacteria from the *Streptomyces* family. These molecules are toxic to most crustaceans but non-toxic to mammals and are used in pesticides and anti-parasitic drugs.

Explanations

Concepts and Terms

Avermectins: These are macrocyclic lactones produced by *Streptomyces* bacteria. They are bactericidal molecules that help the bacteria gain dominance in their microenvironment.
Toxicity: Avermectins are highly toxic to most crustaceans but non-toxic to mammals, making them safe for use in agricultural and medical contexts.

Applications

Pesticides

- Avermectins are used in crop protection to control pests.

Anti-parasitic Drugs

- They are also used to treat parasitic infections in animals and humans, such as head lice, mites, and ticks.

Chemical Structure

A chemical structure of avermectin is shown, highlighting it as a water-insoluble compound.

Visuals

Image

- An image of *Streptomyces* bacteria producing toxins is provided.

Examples of Avermectin-based products

- Solutions for treating mites or ticks.
- Paint for ship hulls.

Notes

- **Avermectin-based Paint for Ship Hulls**: This is an example of preventing biofouling, as it prevents the attachment and growth of aquatic organisms on ship hulls, enhancing their performance and longevity.

Summary and Explanation of Slide 76 on BIOFOULING AND BIOGLUES

Summary

The slide illustrates that Ivermectin is inefficient in preventing barnacle adhesion on hard coatings.

Explanations

Concepts and Terms

Ivermectin: A medication used to treat many types of parasite infestations which is here being tested as an anti-fouling agent.
Barnacles: Marine organisms that often adhere to hard surfaces in the water, causing biofouling.
Hard Coatings: Surfaces that are rigid and used typically in marine environments to protect structures from the harsh conditions.

Diagrams and Data

Without Ivermectin

- The diagram on the upper part shows a cross-section of a hard coating with small barnacles and an early hard baseplate developing into adult barnacles, indicating that there is no penetration by the treatment.

With Ivermectin

- The lower part of the diagram shows the same scenario, but with the addition of Ivermectin (labeled as ”Iv” in the coating), which also results in the growth of adult barnacles, indicating that Ivermectin does not prevent biofouling in this context.

Notes

- *Biofouling*: The accumulation of microorganisms, plants, algae, or small animals on wetted surfaces, often causing structural or operational problems.
- Ivermectin being ineffective on hard coatings implies the need for alternative solutions or additional agents to combat biofouling in marine applications.

Summary and Explanation of Slide 77 on BIOFOULING AND BIOGLUES

Summary

The slide illustrates the effect of Ivermectin on soft coatings in preventing barnacle attachment.

Explanation

Without Ivermectin

Barnacles (small and adult) attach to the coating on the support structure.
Over time, barnacles penetrate the coating, adhering strongly to the hard baseplate.

With Ivermectin

Ivermectin (denoted as ”Iv”) within the coating causes intoxication in the barnacles.
This intoxication leads to detachment of the barnacles, preventing strong adherence and penetration.

Notes

Ivermectin

- This is a medication traditionally used to treat parasitic infections, but here it's shown to be effective in antifouling by preventing barnacle attachment.

Soft Coatings

- These are coatings applied on surfaces to prevent biofouling. They can be more susceptible to barnacle attachment without effective antifouling agents.

Penetration vs. Detachment

- The graphics show that without Ivermectin, barnacles penetrate and anchor themselves into the coating. With Ivermectin, they become intoxicated and detach, preventing strong adherence.

Understanding these points is crucial for studying antifouling strategies in marine environments.

Summary and Explanation of Slide 78 on BIOFOULING AND BIOGLUES

Summary

This slide presents the outcomes of long-term experiments with biofouling on a boat's hull and propeller using different coatings, specifically avermectin paint versus traditional paint.

Explanations

Concepts and Terms

Biofouling: Accumulation of microorganisms, plants, algae, or small animals on wetted surfaces, often causing damage or inefficiency.
Avermectin: A class of anti-parasitic agents known to have antifouling properties.
Traditional Paint: Typically used for protecting surfaces but less effective against biofouling compared to specialized coatings.

Details

Left Image

- Shows a ship hull after a 4-month testing period in Swedish coastal water.
- The hull was divided into two sections: one painted with avermectin and the other left as a control.

- The avermectin surface shows reduced fouling compared to the control.

Right Image

- Exhibits a ship propeller after cleaning.
- The inner propeller, treated with avermectin paint, shows substantially less fouling compared to the outer propeller, which was painted with traditional paint.

Notes

- These images illustrate the efficacy of avermectin-based coatings in preventing biofouling, potentially leading to reduced maintenance costs and enhanced performance for marine vessels.

Summary and Explanation of Slide 79 on BIOFOULING AND BIOGLUES

Summary of Slide

The slide illustrates biosurfaces with mechanical killing abilities. It focuses on how nanopillars on surfaces such as those of gecko skin and cicada wings can penetrate bacterial cell walls, causing them to rupture.

Explanation of Concepts, Terms, and Diagrams

Nanopillars and Bacterial Rupture

Nanopillars: These are microscopic, pillar-like structures present on certain natural surfaces.
Bacterial Cell Wall Penetration: As depicted, nanopillars penetrate the bacterial cell wall, leading to cell rupture and death.

Examples of Biosurfaces

Gecko Skin (c2, c3)

- The SEM images show the nanopillar structures on gecko skin which are effective against *Porphyromonas gingivalis*.

Cicada Wings (a1, a2, a3)

- The images further show cicada wings' nanopillars interacting with *Pseudomonas aeruginosa*.

Diagrams

Diagram (a)

- This illustrates the interaction between cicada wing nanopillars and bacterial cells under an AFM (Atomic Force Microscopy).

Graph (b)

- It shows the height measurement over time, indicating the point (̃200 nm) where bacterial cell rupture occurs due to nanopillar penetration.

Notes

- *Mechanical Killing Abilities*: This method represents a non-chemical approach to bacterial eradication, potentially advantageous in reducing antibiotic resistance.
- *Applications*: Such surfaces can have applications in healthcare (reducing infections on medical devices) and other areas where bacterial contamination is an issue.

Summary and Explanation of Slide 80 on BIOFOULING AND BIOGLUES

Summary

This slide discusses the creation of artificial surfaces with nanospikes using modern nanofabrication techniques like lithography and etching, focusing on different materials and their effects on various bacteria and cells.

Explanations

Concepts and Terms

Nanofabrication Techniques: Methods such as lithography and etching used to create structures at the nanometer scale.
Artificial Surfaces: Surfaces engineered to have specific properties through the addition of nanoscale features.

Types of Nanospikes and Effects

Black Silicon (Nanograss)

- Diameter: 220 nm
- Height: 4 μm
- Effects: Lethal to *Escherichia coli*, *Staphylococcus aureus*, and mammalian cells (mouse osteoblasts)

Diamond Nanocone Surface

- Diameter of Tips: 10-40 nm
- Width of Nanocones: 350 nm - 1.2 μm
- Height: 3-5 μm
- Effects: Lethal to *Pseudomonas aeruginosa* (*P. aeruginosa*)

Diamond Coated Black Silicon (NanoNeedles)

- Short Needle Height: 0.5-1 μm
- Long Needle Height: 15-20 μm
- Effects: Lethal to *Pseudomonas aeruginosa* (*P. aeruginosa*)

Notes:

- The surfaces with nanospikes are designed to physically disrupt bacterial and cell membranes, leading to their death.
- These findings are significant for applications in sterilization, preventing biofouling, and creating anti-bacterial surfaces.

Source

Tripathy et al., *"Advances in Colloid and Interface Science"* (2017).

Summary and Explanation of Slide 81 on BIOFOULING AND BIOGLUES

Summary

The slide explains how biofilm formation leads to the failure of orthopedic implants through a series of biological processes.

Explanations

Concepts and Terms

Biofilm Formation: Bacterial adherence to the implant surface leads to biofilm formation.
Acute Inflammation: The presence of the biofilm triggers an initially acute inflammatory response.
Chronic Inflammation: If the inflammation persists, it transitions into chronic inflammation.
Periprosthetic Infection (PI): Chronic inflammation can lead to a periprosthetic infection.
Fibrosis and Micromovement: These ensuing conditions cause fibrosis (thickening of connective tissue) and micromovement (slight movement of the implant).
Osteolysis: This process involves the breakdown of bone tissue, leading to implant failure.
Foreign Body Reaction: Proteins and cells attach to the implant, causing a foreign body reaction, which may inhibit osseointegration (the bonding of the implant to the bone).

Outcomes: Depending on the biological responses, the implant either fails or integrates solidly into the bone.

Notes:

- *Osseointegration:* Essential for the long-term stability and success of the implant.
- *Osteolysis and implant failure:* Critical conditions to prevent for ensuring the longevity of orthopedic implants.

Summary and Explanation of Slide 82 on BIOFOULING AND BIOGLUES

Summary

The slide talks about the application of nanopatterned titanium surfaces to orthopedic implants to obtain bactericidal effects.

Explanations

Concepts and Terms

Concept: The idea is to create micro-/nanopatterned surfaces on titanium to kill bacteria. This is primarily relevant for orthopedic implants to prevent infections.
Images:

- *Left Image*: Shows the structure of Titania nanowire arrays at a scale of 1 μm.
- *Middle Image*: Shows Ti alloy nanospike surface at a scale of 500 nm.
- *Diagram*: Illustrates the bactericidal mechanism of Ti alloy nanospike surfaces. The spikes can puncture and kill bacteria cells.

Table: Provides specifics about different nanostructured surfaces and their effectiveness against various bacteria.

- **Titania nanowire arrays**: Diameter 10-15 μm. Effective against motile bacteria, less so against non-motile bacteria.

- **Ti nanopatterned arrays**: Average diameter 40.3 nm. Effective against *P. aeruginosa*.
- **Ti alloy nanospike surface** (Diameter 10 nm, spacing 2 μm height): Lethal to *S. aureus*.
- **Ti alloy nanospike surface** (Diameter 20 nm): Lethal to *E. coli*.

Notes

- The elimination of bacteria on orthopedic implants can significantly reduce post-surgical infections and complications.
- The efficacy varies depending on the types of bacteria and the specifics of the nanotopography used.

Summary and Explanation of Slide 83 on BIOFOULING AND BIOGLUES

Summary

The slide discusses *cleanable crumply surfaces* and their role in long-term biofilm control.

Explanation

Concept of Cleanable Crumply Surfaces

The term refers to surfaces engineered with nano-scale crumples (300 nm) to prevent biofilm formation.

Biofilm Control Cycle

Attachment (Step 1)

- Bacteria start attaching to a surface.

Bactericidal Action (Step 2)

- The surface exhibits properties that kill the attached bacteria.

Detachment of Dead Cells (Step 3)

- Dead bacterial cells are detached from the surface.

Clean Surface (Step 4)

- The surface is now clean and ready for the next cycle of attachment, thereby maintaining long-term biofilm control.

Comparative Images and Data

Planar vs. Nano-crumpled Surfaces

- *Planar (Smooth)*: Shows a higher accumulation of bacteria (Staphylococcus aureus).
- *Nano-crumpled*: Shows significantly less bacterial accumulation.

SEM Images

- Display the physical condition of the surfaces and accumulation of bacteria.

Fluorescent Images

- Demonstrate live and dead bacteria on the surfaces, indicating the effectiveness of nano-crumpled surfaces in reducing biofilm.

Notes:

- The study referenced is Tokmedash et al, Advanced Materials Interfaces (2023).
- The crumpled surfaces enhance the detachment of bacteria, making them easier to clean and maintain, thus preventing biofilm formation effectively.

Summary and Explanation of Slide 84 on BIOFOULING AND BIOGLUES

Summary

The slide demonstrates the effectiveness of *cleanable crumply surfaces* in reducing biofilm formation of *S. aureus* and *E. coli* compared to flat and static controls.

Explanations

Concepts and Terms

Biofilms: A biofilm is a community of microorganisms that stick to each other and to surfaces. The slide shows images and data reflecting biofilm formation in different conditions.
Conditions:

- *Flat Control*: Standard control surface.
- *Static Control*: Surface that does not undergo any stretching.
- *On-Demand Stretching (3 min)*: Surface that undergoes mechanical stretching for 3 minutes, designed to disrupt biofilm formation.

Diagrams and Data

Images:

- *S. aureus Biofilm*: Visually, significantly fewer biofilms are formed on the *On-demand stretching* surface compared to flat and static controls.

- *E. coli Biofilm*: Similarly, photos indicate a reduction in biofilm formation on the *On-demand stretching* surface.

Graphs:

- **Y-axis (Relative biofilm %) for both *S. aureus* and *E. coli***: Percentage of biofilm formation relative to control conditions.
- **Statistical significance**:
  - For *S. aureus*: P-values are $P < 0.0001$ and $P = 0.0016$ for static and on-demand stretching conditions, respectively.
  - For *E. coli*: P-values are $P < 0.0001$ and $P = 0.0013$ for static and on-demand stretching conditions, respectively.

Notes:

- *Tokmedash et al, Advanced Materials Interfaces (2023)*: This indicates the source of the study and can be referenced for more in-depth understanding.
- The slide effectively illustrates the potential of mechanically adaptable surfaces to minimize biofilm formation, which is significant for both environmental and biomedical applications.

Summary and Explanation of Slide 85 on BIOFOULING AND BIOGLUES

Summary

This slide presents research findings on the compatibility of crumpled surfaces with eukaryotic cells. The study investigates the effect of varying the number of bilayers in crumpled nano/microstructures on cell adhesion and density.

Explanations

Concepts and Terms

Cleanable Crumply Surfaces: These are nano/microstructured surfaces that can be cleaned easily. The study explores their biocompatibility, particularly with eukaryotic cells.
Cell Density vs. Bilayer Number (n):

- *Figure a*: Microscopic images showing cell density for different bilayer numbers (n = 0, 1, 3, 6, 10, 20). It is evident that cell adhesion increases with the number of bilayers.
- *Figure b*: Graph depicting cell density as a function of the bilayer number. As the number of bilayers increases, so does the cell density, with a notable increase observed between n=10 and n=20.

Key Observation:

- The crumpled LbL (Layer-by-Layer) films with varying bilayer numbers do not negatively impact cell viability.

- A significant increase in cell adhesion was observed when the bilayer number increased from 10 to 20.

Notes

- This data is critical for applications where biocompatibility of materials is crucial, such as in medical implants or bioengineering.
- Further research might be needed to explore the mechanical properties and potential use cases of these crumpled surfaces in different environments.

Summary and Explanation of Slide 86 on BIOFOULING AND BIOGLUES

Summary

This slide discusses *Anti-biofouling strategies - IV* with a focus on the method of shedding or sloughing, exemplified by various marine organisms and the mammalian gastrointestinal system.

Explanations

Concepts and Terms

Biofouling: The accumulation of microorganisms, plants, algae, or animals on wetted surfaces, such as ships' hulls, pipes, and underwater sensors.
Anti-biofouling strategies - Shedding/Sloughing: This strategy involves the periodic shedding of outer layers to remove biofouling organisms.

Examples of Organisms Using Shedding/Sloughing

Red Algae: Marine algae that may use shedding to prevent organism accumulation.
Corals: Utilize shedding of their outer layer to avoid biofouling.
Stone Fish: Example of a fish that might periodically slough off its skin to remove parasites or algae.
Sea Urchin: They can shed their spines and outer body surface to avoid biofouling.

Mammalian Gastrointestinal System: The continuous turnover of the epithelial lining in the gastrointestinal tract helps in anti-biofouling by shedding off bacteria and food particles adhered to the surface.

Notes:

- **Practical Implication**: Understanding these natural anti-biofouling strategies provides insights into developing new coatings or materials for industrial use, mimicking these natural mechanisms to reduce maintenance costs and improve the longevity of marine and other water-exposed structures.