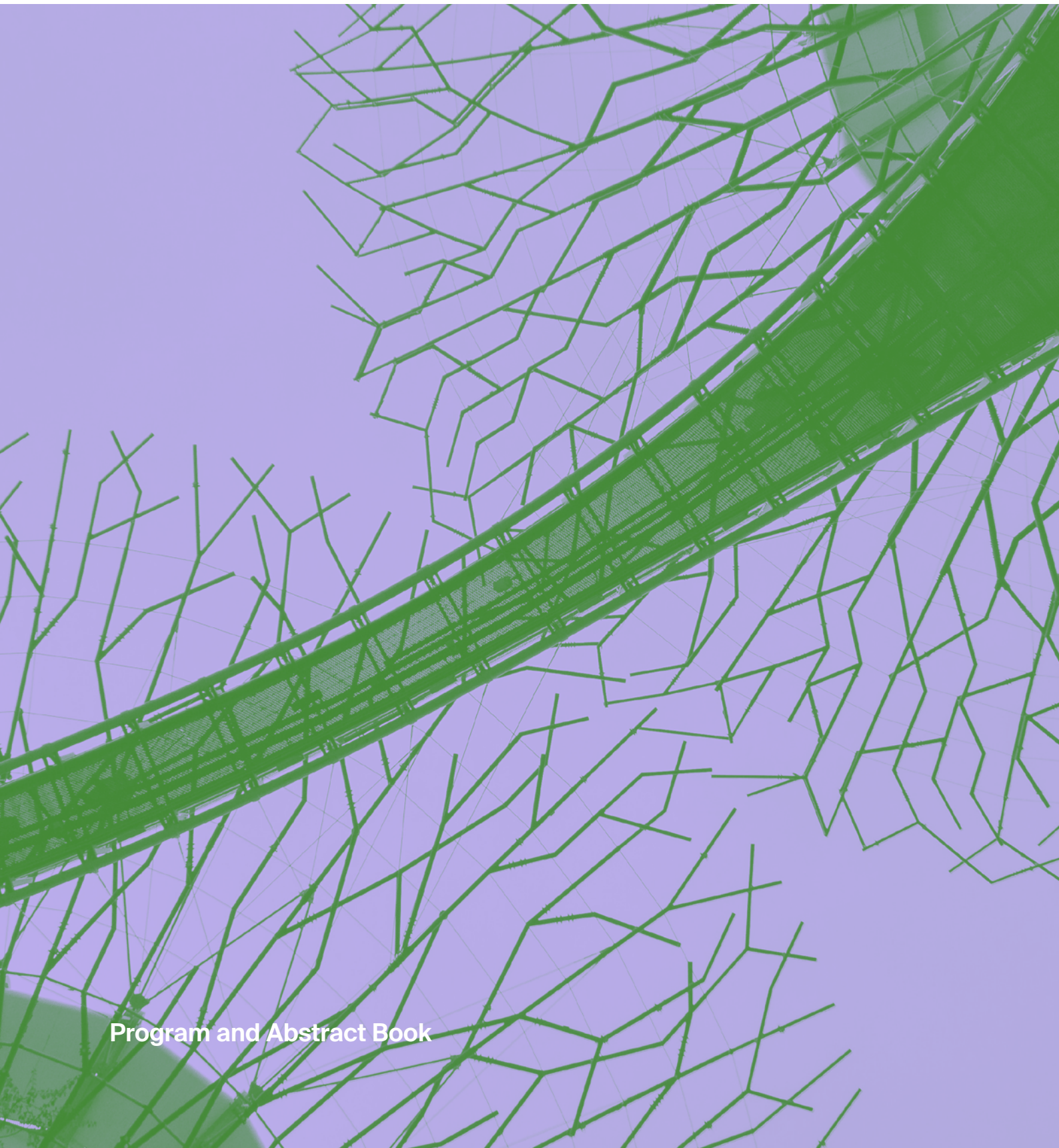
IOCB 2024 Conference

The 1st International Online Conference on Biomimetics

15–17 May 2024 | Online



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The 1st International Online Conference on Biomimetics

15–17 May 2024 | Online

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Prof. Dr. Giuseppe Carbone

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Prof. Dr. Xu Hou
Prof. Dr. Marc Weissburg
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Conference Secretariat

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Welcome from the Chair

Dear Colleagues,

The 1st International Online Conference on Biomimetics, with a focus on "Advances in bioinspired materials, biomimetic design and device, bioinspired surfaces and interfaces, bioinspired robotics and bioinspired sensors", will be held from **15–17 May 2024**. The main purpose of the conference is to promote biomimicry and bionics, and it is dedicated to research that relates to the most basic aspects of living organisms and the transfer of their properties to human applications and man-made devices.

This conference is an excellent opportunity for researchers and scientists in the field of biomimetics and bionics to interact with each other, communicate with colleagues, learn from each other, share ideas and experiences, jointly solve problems, and suggest alternative solutions for a better future in the bionics. A distinct advantage of this virtual international conference is that the participants are not required to travel and can simply attend the conference regardless of their location. Participants do not need to seek financial support for travel, nor do they need to leave the comfort of their home, office, and/or family to book a trip and, consequently, adjust to the corresponding time zone.

In the virtual conference setting, while the presenters can deliver live presentations simultaneously, the participants can contribute to the discussion and provide feedback orally and/or using the "Chat" and "Reaction" functions.

The main topics of this conference include:
Biomimetics of Materials and Structures
Biomimetic Design, Constructions, and Devices
Biomimetic Surfaces and Interfaces
Design and Control of Bioinspired Robotics
Biomimetic Application of Insect Functional Morphology

All accepted abstracts will be published on the conference's website. Participants are expected to submit an abstract of 200 to 300 words and should refer to the abstract preparation guidelines at "Instructions for Authors".

After the conference, the participants may submit a full paper to MDPI's *Biomimetics* journal. After the review process, the authors of the accepted papers will receive a **20% discount** on the APC before the paper is published in *Biomimetics*.

On behalf of the Organizing Committee, I welcome your attendance to the **1st International Online Conference** on Biomimetics on, "Advances in bioinspired materials, biomimetic design and device, bioinspired surfaces and interfaces, bioinspired robotics and bioinspired sensors".

Prof. Dr. Giuseppe Carbone
Conference Chair
Department of Mechanics,
Mathematics and Management,
Polytechnic University of Bari, Italy

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General Information

biomimetics

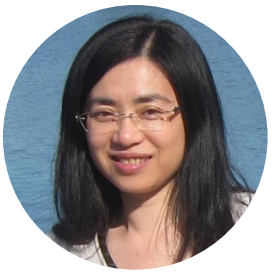
an Open Access Journal by MDPI

Biomimetics (ISSN 2313-7673) is an open access journal regarding biomimicry and bionics, dedicated to research that relates to the most basic aspects of living organisms and the transfer of their properties to human applications. The journal aims to provide a forum and a survey for researchers and professionals in the fields of materials science, mechanical engineering, nanotechnology and biomedicine interested in exploiting biologically inspired designs in engineering systems, technology and biomedicine aimed to developing novel solutions that enable sustainable innovation.

Journal Webpage: https://www.mdpi.com/journal/biomimetics.

Session Chairs

Prof. Dr. Xu Hou
Institute of Electrochemical Science and Engineering; State Key Laboratory of Physical Chemistry of Solid Surfaces; College of Chemistry and Chemical Engineering and College of Physical Science and Technology, Xiamen University, Xiamen, China



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Brook Byers Prof. of Sustainability and Co-Director of the Center of Biologically Inspired Design, School of Biological Sciences, Georgia Institute of Technology, Atlanta, GA, USA

Prof. Dr. Joseph Ayers
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Dr. Cheng-Quan Cao
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Dr. Chu-Chu Li
Functional Morphology and Biomechanics, Kiel University, Kiel, Germany

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Dr. Muhammad Ullah
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Invited Speakers

Professor Jianying He
Department of Structural Engineering, Norwegian University of Science and Technology, Trondheim, Norway

Professor Chaozong Liu
Department of Ortho and MSK Science, University College London, London, The United Kingdom

Assoc. Prof. Yuhang Hu
Georgia Institute of Technology, Atlanta, GA, USA

Assoc. Prof. Yu Shrike Zhang
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Professor Simon Yang
Advanced Robotics & Intelligent Systems (ARIS) Lab, School of Engineering, University of Guelph, Guelph, ON, Canada

Professor Stanislav N. Gorb
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Dr. Hamed Rajabi
London South Bank University, London, UK

Dr. Jianing Wu
Sun Yat-Sen University, Guangzhou, China

Dr. Mingxia Sun
College of Life Sciences, Tianjin Normal University, Tianjin, China

Program at a Glance

The 1st International Online Conference on Biomimetics
15–17 May 2024

	15 May 2024 (Wednesday)	16 May 2024 (Thursday)	17 May 2024 (Friday)
Morning	**Session 3.** Biomimetic Surfaces and Interfaces	**Session 6.** Biomimetic Application of Insect Functional Morphology	**Poster Session**
	Break	Break	Break
Afternoon	**Session 2.** Biomimetic Design, Constructions and Devices **Session 4.** Design and Control of Bioinspired Robotics	**Session 1.** Biomimetics of Materials and Structures	

IOCB Program

15 May 2024 (Wednesday)
Time: 9:00 (CEST, Basel) | 03:00 (EDT, New York) | 15:00 (CST Asia, Beijing)
Session 3. Biomimetic Surfaces and Interfaces

Time in CEST	Speaker	Title
9:00–9:05	Welcome from the conference chair--**Prof. Dr. Giuseppe Carbone**	
9:05–9:10	Welcome from the session chair-- **Prof. Dr. Yongmei Zheng**	
9:10–9:30	**Prof. Dr. Jianying He** Invited Speaker	From Fish Scales to Dynamic Ice Removal Mechanisms
9:30–9:50	**Prof. Dr. Jianjun Wang** Invited Speaker	Bio-Inspired Ice Controlling Materials for Cryopreservation
9:50–10:10	**Prof. Dr. Chaozong Liu** Invited Speaker	Engineering Biomimetic Osteochondral Scaffold for Early Intervention Of Osteoarthritis
10:10–10:25	**Katarzyna Pastuszak** Selected Speaker	Penetration Mechanism Of The Model Based on Legionella Gormanii Bacterial Membranes Using the LL-37 Peptide
10:25–10:40	**Elena Ungureanu** Selected Speaker	Development and Characterization of Hydroxyapatite Coatings with a Biomimetic Plate-Like Morphology
10:40–10:55	**Sebastien Mouchet** Selected Speaker	Infrared Management in Nature And Bioinspired Applications
10:55–11:10	**Agnieszka Ewa Wiącek** Selected Speaker	Physicochemical Characterization of Tio2/Polysaccharide Systems in Terms of Biocompatibility

15 May 2024 (Wednesday)
Time: 14:00 (CEST, Basel) | 08:00 (EDT, New York) | 20:00 (CST Asia, Beijing)
Session 2. Biomimetic Design, Constructions and Devices
Session 4. Design and Control of Bioinspired Robotics

Time in CEST	Speaker	Title
14:00–14:05	Welcome from the session host—**Prof. Dr. Ille C. Gebeshuber**	
14:05–14:25	**Prof. Dr. Ille C. Gebeshuber** Invited Speaker	Bioinspired Growth and Decay - A New Paradigm for Materials Science
14:25–14:45	**Prof. Antonio Concilio** Invited Speaker	Practiced Applications of Aerospace Morphing Devices: Considerations and Perspectives
14:45–15:00	**Zeyi Zhang** Selected Speaker	Optimized Design and Propulsion Performance of the Robotic Sea Lion Foreflipper
15:00–15:15	**Zhizhen Jiang** Selected Speaker	Contact Behaviours of Biomimetic Spatula-Shaped Adhesive Microstructures on Rough Surfaces Using Finite Element Simulations
15:15–15:30	**Silvia Titotto** Selected Speaker	Bridging Biomimetics and Additive Manufacturing for Dynamic Design Solutions
15:30–15:45	**Almajd Alhinai** Selected Speaker	Design and Development of Bio-Inspired Fixed-Wing Flying Robots
15:45–16:00	**Ricardo Palmieri** Selected Speaker	Parametric Algorithms Used as a Design Tool for Auxetic Structure Development
16:00–16:05	Welcome from the session host—**Prof. Simon Yang**	
16:05–16:25	**Prof. Simon Yang** Invited Speaker	Bio-Inspired Intelligence with Application to Control of Various Robotic Systems
16:25–16:40	**Freddie Coen** Selected Speaker	Caninoid Necro-Robots: Geometrically Selected Rearticulation of the Canine Mandible
16:40–16:55	**Peter L. Bishay** Selected Speaker	Cgull: a Non-Flapping Seagull-Inspired Composite Morphing Drone
16:55–17:00	**Alistair Daynes** *Learn Biomimicry*	Nature's Blueprint: The Future of Learning Biomimetics

16 May 2024 (Thursday)
Time: 9:00 (CEST, Basel) | 03:00 (EDT, New York) | 15:00 (CST Asia, Beijing)
Session 6. Biomimetic Application of Insect Functional Morphology

Time in CEST	Speaker	Title
9:00–9:05	Welcome from the session chairs--**Dr. Ming-Xia Sun, Prof. Si-Qin Ge, Dr. Cheng-Quan Cao, Dr. Chu-Chu Li**	
9:05–9:20	**Prof. Stanislav N. Gorb** Invited Speaker	From the Insect Adhesion to Snake Slithering: Tribology and Contact Mechanics Aspects of Biological Surfaces
9:20–9:35	**Prof. Hamed Rajabi** Invited Speaker	Mechanical Intelligence in Insect Wings: The Role of the Basal Complex in Wing Shape Morphing
9:35–9:50	**Prof. Jianing Wu** Invited Speaker	Synergy in Nature: Exploring Bee-Flower Interactions and Biomimetic Innovations
9:50–10:05	**Prof. Mingxia Sun** Invited Speaker	Wettability, Adhesion and Optics of Insect Wings and Biomimetic Application
10:05–10:15	**Siqin Ge** Selected Speaker	The Bionic Application Potential of Insect Functional Structures
10:15–10:25	**Jieliang Zhao** Selected Speaker	Bionic Design of Morphing Nose Cone for Aerospace Vehicle Based on the Honeybee Abdomen
10:25–10:35	**Guillermo J. Amador** Selected Speaker	Capillary Adhesion of Stick Insects
10:35–10:45	**Chuchu Li** Selected Speaker	Relationship between Structure, Mechanical Properties and Function in Locust Cuticle
10:45–10:55	**Chufei Tang** Selected Speaker	Natural Structural Regulation of Mid-Infrared Radiation in Butterfly Wing Scales and Their Potential in Ecological Adaptation
10:55–11:05	**Zhengzhong Huang** Selected Speaker	The "Screw-Nut" Structure of the Frog-Legged Beetle Sagra Femorata
11:05–11:15	**Yuanyuan Lu** Selected Speaker	Functional Morphology Studies on The Cuticle of Spherical Shape Beetles
11:15–11:25	**Huan Shen** Selected Speaker	The Unique Flight Strategies Adopted by Butterflies When Landing on Vertical Surfaces
11:25–11:35	**Giuliana Flavia Cangelos** Selected Speaker	Modularity in the Insect World As a Strategy for Bio-Inspired and Sustainable Design
11:35–11:45	**Ateeq Ur Rehman** Selected Speaker	Full Cocoon vs. Cut and Flattened Walls: Comparing Stab Testing Methods as Applied to Bombyx Mori Silk Cocoons

16 May 2024 (Thursday)
Time: 15:00 (CEST, Basel) | 09:00 (EDT, New York) | 21:00 (CST Asia, Beijing)
Session 1. Biomimetics of Materials and Structures

Time in CEST	Speaker	Title
15:00–15:05	Welcome from the session chair—**Prof. Xu Hou**	
15:05–15:10	Welcome from the session host--**Prof. Daniel Ruiz**	
15:10–15:30	**Prof. Yu Shrike Zhang** Invited Speaker	Biofabrication of Human Tissue-Mimetics
15:30–15:50	**Prof. Yuhang Hu** Invited Speaker	Chemomechanics of Dynamic "Living" PolymersAffiliation: Georgia Institute of Technology
15:50-16:10	**Prof. Salvio Suárez–García** Invited Speaker	Mussel-Inspired Approaches to Produce Multifunctional Bioinspired Materials for Their Application in Biomedicine.
16:10–16:25	**Sepehr Hajali Eraghi** Selected Speaker	Mechanical Intelligence in Insect Wings: The Role of The Basal Complex in Wing Shape-Morphing
16:25–16:40	**Xiaofei Ma** Selected Speaker	Study on the Mechanical Properties and Energy Absorption Characteristics of Bionic Variable-Amplitude TPMS Structures
16:40–16:55	**Samudrika Aththanayaka** Selected Speaker	Evaluation of the in Vitro Anti-Inflammatory Potential of Biogenically Synthesized Silver/Silver Oxide Nanoparticles Utilizing Pumpkin Agricultural Byproducts
16:55–17:10	**Jackeline Riqueira** Selected Speaker	Optimization of Bioinspired Scaffolds to Enhance Cell Viability and Enable Tissue Growth
17:10–17:25	**Banani Kundu** Selected Speaker	Mimicking the Dynamic Mechanical ECM Using Engineered Biomaterials to Investigate Cellular Crosstalk
17:25–17:40	**Praveenkumar Patil** Selected Speaker	Predicting the Flexural Modulus of Variable-Pitch-Angle, Porous-Bouligand-Structured 3D-Printed Polymer
17:40–17:55	**Ateeq Rahman** Selected Speaker	Assessing the removal efficiency of ibuprofen in an aqueous solution using *Acacia Erioloba* nanoparticles

17 May 2024 (Friday)
Time: 9:00-10:30 (CEST, Basel) | 03:00–4:30 (EDT, New York) | 15:00–16:30 (CST Asia, Beijing)
Live Poster Session

Presenter List

Poster Session	
Name	**Title**
KM Samaun Reza	How Nanopores and Microcavities Control the Light Reflectance Properties of Snake Ventral Scales
Mukunda Adhikari	Diatom frustule-inspired bridges: a fusion of art, architecture and mechanical design
Atkinson Irina	Effect of vitamin D3 functionalization on osteogenic differentiation of dental pulp stem cells and genotoxicity in bioinspired 3D scaffolds based on marine sponge
Letícia Severino	Assessment of Biological Carbonation Strategies in the Marine Ecosystem and Potential Applications in Cementitious-Based Products via a Biomimetic Model
Aihong Ji	Research on the flight characteristics of beetles and the design of bionic aircraft
Yiheng Song	Flexural Enhancement in Beetle-Inspired Sandwich Plates with a Large Height-to-Thickness Ratio Core
Katarzyna Pastuszak	Thermodynamic analysis of interactions in Langmuir monolayers imitating bacterial membranes
Deyou Li	Influence of Bionic Leading-edge Protuberances on the Horizontal Axis Wind Turbine
Aditi Kishore	Autonomous Aquatic Sentinels: Advancing Water Quality Assessment with Non-Intrusive Biomimetics Approach
Florian Zischka	Butterfly Wing Scales as Inspiration for Multifunctional Building Surfaces
Bartosz Leśniewski	Extreme biomimetic approach: melting of steel and copper on carbonised 3D spongin scaffolds
Markus Zimmerl	Utilizing passive radiative properties of Silver Ants
Francisco Antonio Godínez Rojano	Bioinspired Snapping-Claw Apparatus to Study Flow-Accelerated Corrosion of Low-Carbon Steel
Pieter Samyn	Biomimetic approaches for design of antimicrobial paper barrier coatings with hierarchical surface structure
Cornelia Pichler	Analyzing the tribological combination of microstructure and lubricant in beetle joints for the development of environmentally friendly lubricants
Omobolanle Omoteso	The use of plant-derived biomaterials as drug formulation excipients: an application of biomimetics in dosage form development
Noelia D'Elía	A bioinspired material for bone tissue regeneration: The use of Ganoderma sessile mycelium as a microstructure director
Heting Hong	Can Biomimetic Superhydrophobic Surfaces Resist Underwater Biofouling?
Angelina Ivanova	Towards Improved Remineralization: Calcium Ion incorporation Into Enamel Induced Using Aspartic Acid In Vitro
Anita Kubiak	Biomimetic Synthesis of Lepidocrocite on Marine Spongin Scaffolds: Mechanistic Insights and Multifunctional Potential
Izabela Dziedzic	Biomimetic application of Ianthella basta demosponge capillary structured chitin scaffolds
Junfei Li	Bio-inspired Neural Network for Real-time Evasion of Multi-robot Systems in Dynamic Environments
Annabelle Aish	Bioinspire-Explore: Browsing Biodiversity Data for Bioinspiration
Xiangli Zeng	Mechanism of motile plants and robots inspired by plants
Jun-Hyeog Jang	Engineering Multifunctional Biomimetic ECM Proteins with Elastin-Like Polypeptide Fusion for Enhanced Tissue Regeneration

About Us

Launched in 2009 by MDPI, Sciforum is an event management platform that supports open science by offering the opportunity to participate in, as well as to organize, academic events. Having hosted hundreds of events (be it in-person events, virtual events, or webinars), Sciforum helps organizers reduce their administrative efforts by providing a comprehensive set of tools to successfully manage academic events.

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Abstracts

Session 1. Biomimetics of Materials and Structures

sciforum-084963: A Bioinspired Material for Bone Tissue Regeneration: The Use of Ganoderma Sessile Mycelium as a Microstructure Director

Noelia Laura D'Elía [1], Javier Sartuqui [1], Damian Placente [1], Pablo Postemsky [2] and Paula Messina [1]

[1] INQUISUR–CONICET, Department of Chemistry, Universidad Nacional del Sur, CPB B8000 Bahía Blanca, Argentina
[2] Laboratory of Biotechnology of Edible and Medicinal Mushrooms, Centro de Recursos Naturales Renovables de la Zona Semiárida (CERZOS-UNS/CONICET), Camino de La Carrindaga Km7, 8000 Bahía Blanca, Buenos Aires, Argentina

Introduction

The development of new strategies to repair large segmental bone defects is currently an ongoing challenge all around the world, and biomaterials suitable for dealing with this are in high demand. An important aim in this field is to achieve simultaneously both the mechanical and biological requirements of the implant site.

Methodology

In this study, we propose obtaining a bioinspired bone tissue substitute using the stiff and modulable mycelium of Ganoderma sessile. The mycelium was cultured on a substrate composed of alginate crosslinked by hydroxyapatite nanoparticles (ALG-HAn), with in vitro osteogenic properties previously verified by the authors. Then, the mycelium was inactivated and sterilized by autoclaving to obtain the final biomaterial.

Results

Using scanning electron microscopy (SEM), it was possible to confirm that the mycelium acts as a directing agent of the biomaterial microstructure. The mycelium colonized the ALG-HAn substrate, leading to the formation of a trabecular bone-like network with a hierarchical structure. Moreover, static water contact angle assays demonstrated that the presence of ALG in the membranes significantly reduced the hydrophobicity of the biomaterials. Finally, to test the interaction between blood cells and biomaterial, we verify the lack of hemolysis in human plasma samples.

Conclusion

The promising results of this work will provide a new perspective for the future development of mycelium-based biomaterials applied for bone tissue regeneration.

sciforum-086655: A Mitigating Strategy for Urban Heat Islands: The Biomimicry Approach Case of Delhi

Anushka Dhankhar [1,2], Anway Kundu [1], Neha Basumatary [1], Sanika Khune Khune [1] and Amit Kumar Jaglan [3]

[1] Student—School of Planning & Architecture, New Delhi
[2] Student—Department of Architecture
[3] Department of Architecture, School of Planning & Architecture, New Delhi,110002, India

The need for widespread urbanisation has increased due to population growth. Because of this, there is now a phenomenon called an Urban Heat Islands (UHIs), which form when there are greater air levels or surface temperatures in urban areas than in rural areas. The local climate, the urban fabric, the materials used, and the surfaces all contribute to UHIs. Architects (2014) found that with every 0.6 °C increase in midsummer temperature, peak hour power demand climbs 1.5 to 2% for Delhi. It has been projected that for every degree over a (locally specified) cut-off point, mortality rates for populations inside the European Union increase by 1 to 4%. However, in the middle of the hot buildings and humid streets, nature provides us with a multitude of clever cooling strategies that we might imitate. A creative approach to problem solving, bioinspiration, also called biomimicry, draws inspiration from nature to develop and innovate across a range of industries. It offers pleasing aesthetics in addition to useful solutions. A few of the bio-inspired techniques include using materials with high reflectance, i.e., those which are similar to the skin of Saharan ants; imitating the colour and reflectance variations of zebra skin for differential heating; and adding water features and vegetation that are modelled after human skin's evapotranspiration. Quite a few architectural components use these biomimetic concepts. Sun protection is actively provided by kinetic facades. Albedo is increased by the use of materials with high reflectivity. Differential heating caused by the incorporation of materials with varying degrees of reflectance creates convection currents. A localised cooling effect is achieved by the interspersion of green walls, water features, and porous materials that retain water. The goal of this study is to develop sustainable urban environments with lower UHI impacts using biomimetic concepts, such as green infrastructure and bio-inspired materials.

sciforum-088720: Assessing the Removal Efficiency of Ibuprofen in an Aqueous Solution Using *Acacia erioloba* Nanoparticles

Ateeq Rahman [1], Panduleni Shanyenga Shivute [2] and Shivaprashanth Kumar Kodicherla [2]

[1] School of Science, Faculty of Agriculture, Engineering and Natural Science, Department of Physics, Chemistry & Material Science University of Namibia, Mandumedumefayo-13301, Windhoek, Namibia
[2] Department of Civil, Mining and Process Engineering, Namibia University of Science & Technology. 13 Jackson Kaujeua Street, Windhoek, Namibia

This study highlights the adsorption efficiency of *A. erioloba* Seed Nanoparticles (AESNs) in the removal of ibuprofen from water. Ibuprofen is one of the most commonly used drugs in the world and often makes its way into aquatic resources through improper disposal. The AESNs (adsorbents) were extracted from the *A. erioloba* seed pod via dewaxing, alkali treatment, bleaching, and acid hydrolysis to obtain nanoparticles. These nanoparticles were characterized by SEM analysis. An ibuprofen solution model was prepared via the dissolution of water–methanol at a ratio of 9:1. A calibration curve was prepared with a standard solution of the ibuprofen in a concentration range of 0.001 mg/l–0.010 mg/L. The effect of dosage, pH, time, and temperature in each of the prepared ibuprofen concentrations was determined. Fourier–transform infrared spectroscopy (FTIR) was used to determine functional groups, and scanning electron microscopy (SEM) was used to study the morphology, size, and surface structure of the nanoparticles. UV spectroscopy determined the concentration of ibuprofen after the interaction with the AESN in different parameters, and X-ray diffraction (XRD) was used to determine the crystal structure of the AESN. The Langmuir and Freundlich isotherm models, as well as Brunauer–Emmett–Teller (BET) methods, were applied to optimize the conditions for maximum adsorption and elucidate the surface area of AESNs and the behaviour of AESN as an adsorbent. The Brunauer–Emmett–Teller (BET) results indicate that the surface area was found to be 0.7313 m^2/g and the pore size was 0.001148 cm^3/g. The R^2 0.77 and 0.3710 results indicate that they do not favor both Langmuir and Freundlich isotherm models. The use of a low ibuprofen concentration, i.e., a low dosage, in this study resulted in positive results.

sciforum-086512: Bio-Inspired Design of Lightweight and High-Strength Fiber-Reinforced Polymer Composites for Structural Applications

Zhong Hu

Department of Mechanical Engineering, J. J. Lohr College of Engineering, South Dakota State University, Brookings, SD, USA

The ever-increasing requirements for structural performance drive the research and development of lighter, stronger, tougher, and multifunctional composite materials. In particular, porous structures, heterogeneities, and hybrid composites have attracted great interest from the materials research community. However, strong coupling among the material composition and topology of the porous structure hinders conventional trial-and-error approaches, and current technologies that rely on traditional design and manufacturing techniques are insufficient to effectively solve the pressing challenges facing future societies. This presentation aims to adopt bio-inspired design for structural applications. Bio-inspired design solutions are widely used in different engineering disciplines. However, in structural engineering, these solutions are mainly limited to bio-inspired structures or microstructures, shapes or topologies, and materials, and the applications are mainly used to optimize stiffness, strength, weight, toughness, etc. In this work, carbon fiber-reinforced polymer matrix composite materials were adopted for structural design. In addition, 2D and 3D periodic lattice blocks inspired by biomimetics combined with topological optimization based on finite element modeling and an experimental approach were proposed. Computer modeling and topology optimization, based on finite element analysis, were conducted on the periodic representative volume elements to characterize the designed lattice structural composites' performance. The 3D printing technique was used for prototyping the bio-inspired designed porous structures, and experimental tests were carried out to validate the design methodology. The proposed approach provides a design tool for more affordable, more effective, and higher-performance structural materials.

sciforum-085401: Biogenic Synthesis of Ag Nanoparticles, ZnO Nanoparticles, and Ag@ZnO Nanocomposites as Photocatalysts for the Degradation of Brilliant Blue Dye

Vinidu Gamage [1,2], Gobika Thiripuranathar [2], Upul Nishshanka [3], Namal Priyantha [1], Manisha De Alwis Goonatileke [4], Beth Guiton [4], Siyath Gunawardene [5] and Sumedha Jayanetti [6]

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Utilizing green nanomaterials in a biomimetic setting to treat wastewater emulates the sustainability and efficiency of natural systems. In this study, wood apple (WA) outer shell extract was used as a reducing and stabilizing agent in a simple, inexpensive, and environmentally friendly green approach to synthesize Ag nanoparticles (NPs), ZnO NPs, and Ag@ZnO nanocomposites (NCs) as potential photocatalysts for the degradation of an industrial dye known as Brilliant Blue (BB). Synthesis parameters of Ag NPs, ZnO NPs, and Ag@ZnO NCs were evaluated in this research utilizing various analytical methods. Surface plasmon resonance peaks for Ag NPs, ZnO NPs, and Ag@ZnO NCs were observed at 400–470 nm, 320–370 nm, and 400–500 nm, respectively. The appearance of a Fourier transform infrared band in the 500–700 cm^{-1} region is attributed to the Zn-O bond stretching mode, indicating the formation of ZnO NPs and Ag@ZnO NCs. The SEM images of WA-mediated Ag NPs, ZnO NPs, and Ag@ZnO NCs illustrate spherical, flake, and flower-shapes, respectively, while the average sizes of these three types of particles are determined to be 15.04 ± 5.40 nm, 82.40 ± 3.24 nm, and 12.08 ± 2.91 nm, respectively, as per transmission electron microscopic investigation. Moreover, X-ray diffraction patterns confirm the synthesis of pure crystalline structures, with a face-centered cubic structure for Ag and a hexagonal wurtzite structure for ZnO NPs during the synthesis of Ag@ZnO NCs. The biogenic WA-mediated ZnO NPs show a remarkable photodegradation efficiency of 65.8% under the optimum conditions of catalytic load, pH, and dye concentration, whereas WA-mediated Ag NPs and Ag@ZnO NC show 13.9% and 63.7% photodegradation efficiency, respectively, at 240 min. The study reveals that WA-mediated ZnO NPs and Ag@ZnO NCs exhibit nearly identical photo-catalytic activity against the BB dye, presenting new opportunities for sustainable use in textile and wastewater treatment.

sciforum-086729: Bioinspired Self-Healing Luminescent Lanthanide Bipyridinedicarboxiamide Complexes

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Polymers with photoluminescent centers in their structure are of great interest in the field of bioimaging and could be artificial analogs to green fluorescent protein (GFP) from jellyfish [1]. Along with intrinsic photoluminescence, jellyfish also demonstrate self-healing of their organs, which allow the creatures to survive in aquatic environments [2]. Polymer metal complexes (PMCs) of europium(III) and terbium(III) could be artificial analogs to GFP due to their excellent luminescent properties (Tb^{3+} and Eu^{3+}) and to the bioinertness of PDMS.

Europium(III) and terbium(III)-containing 2,2′-bipyridine-6,6′-dicarboxamide-co-polydimethylsiloxanes (Eu-Bipy-PDMS and Tb-Bipy-PDMS) [3] and their low-molecular complexes $[Tb(BDCA)_2(H_2O)]Cl_3$ and $[Eu(BDCA)_2(H_2O)]Cl_3$ [4] were synthetized by polycondensation and complexation reactions. The structure of the obtained complexes was confirmed by NMR, IR spectroscopy, and XRD analysis. A tensile property study was carried out on a Shimadzu EZ-L-5kN testing machine (RT, constant stretching rate of 10 mm·min^{-1}, sample shape ISO 37 type 3). Photoluminescence spectra and quantum yields (QYs) were studied using a HORIBA Fluorolog-3 spectrofluorometer with an integrating sphere (101 mm in diameter) at RT.

Eu-Bipy-PDMS and Tb-Bipy-PDMS show QYs of 10.5% and 18.5%. The PMCs' structure enables the formation of coordinatively saturated complexes of lanthanide ions and provides good tensile properties to Eu-Bipy-PDMS (1.55 MPa, 185%) and Tb-Bipy-PDMS (1.48 MPa, 190%). The self-healing efficiency of PMCs exceed 90%. $[Tb(BDCA)_2(H_2O)]Cl_3$ and $[Eu(BDCA)_2(H_2O)]Cl_3$ show high QYs of 36.5% and 12.6%, respectively, and can retain them after encapsulation in a semitransparent biocompatible polyethyleneglycol matrix (11.2% and 25.3%, respectively).

Both obtained self-healing luminescent lanthanide-containing PMCs and their low-molecular analogs could be used in bioimaging and theranostics [5].

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sciforum-089448: Biomimetic Design of Long Bones from Human Skeleton for Structural Systems

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The concept of green construction enables a revolutionary change in the construction sector in terms of design, production, and management. One such method is introducing the concept of biomimicry. Biomimicry is utilized in the field of design to solve problems. This paper mainly discusses about the mimicking of human skeleton for structural design. The idea is based on mimicking humerus bone as a tension member and femur bone as a compression member. The optimized members of compression and tension (strut and tie) were put together to form the mimicked king post truss analytically with the conventional cross section truss. Three cases were considered analytically with the average diameter, maximum diameter, and equivalent self-weight to the members of mimicked truss. Experimentally testing was also conducted with the non-destructive test and the point load test. The result shows that the ultimate load carrying capacities of the critical compression member and the tension member were 846.16 kN and 1952 kN, respectively. Meanwhile, the achieved loads were 780.30 kN and 1729 kN. Also, the ratio of analytical stiffness to self-weight was 21.83 mm^{-1} and the ratio of experimental stiffness to self-weight was 19.15 mm^{-1}. Therefore, from the results, it was observed that the equivalent results for mimic truss can be achieved in a truss which is modeled of the equivalent self-weight. Hence, the development and use of structural elements using biomimicry is feasible and will lead to economic, green, and energy efficient structures.

sciforum-086529: Biomimetic Glycerohydrogel Materials Based on Chitosan L- and D-Aspartate

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Biomimetic sol–gel synthesis using alkoxysilane derivatives (gel precursors) and natural polysaccharides (templates) is one of the current directions used for obtaining hybrid hydrogel materials for medical purposes.

In this work, polymeric glycerohydrogels, in the form of thin-film plates, were obtained using biomimetic sol–gel synthesis with silicon tetraglycerolate, chitosan L-(D-)aspartate (CS·L-(D-)AspA), and glucomannan. The surface microrelief of the samples was examined by atomic force microscopy, and the level of supramolecular structuring in their polymer phase was assessed by X-ray diffractometry. A comparative analysis of the adhesion, spreading, and proliferation rate in vitro of epithelial-like cells of the rhesus macaque embryonic kidney MA-104 and epithelial cells of human fibroblasts and keratinocytes in the presence of CS·L-(D-)AspA was carried out.

It has been established our glycerohydrogel plates based on CS·L-AspA and CS·D-AspA are represented by interpenetrating spatial networks of both organic and inorganic nature, filled with a water–glycerol medium. For the CS·L-AspA plates, a predominantly "needle-like" relief is visualized with a predominance of protrusions up to 4.2 μm high, while a "needle-grained" relief is characteristic for the CS·D-AspA ones with protrusions up to 2.8 μm high and pores with diameters of ~3–10 μm. The solid phase from the corresponding plates showed a dense amorphous–crystalline ordering of the polymeric substance compared to the solid phase isolated from CS·L-(D-)AspA in the absence of silicon polyolate networks and a bioinert template. The addition of CS·L-(D-)AspA to the nutrient medium to cultivate MA-104 epithelial cells, human fibroblasts, and keratinocytes accelerates the adhesive and proliferative activity in vitro of the cell cultures tested.

These features allow us to consider our glycerohydrogel plates based on CS·L-(D-)AspA as promising biomimetic substrates to form tissue-engineered structures with a pregiven set of properties and an accelerated growth of populations of epithelial and epitheliopod cell cultures.

sciforum-086730: Chameleon-like Self-Healing Flexible Materials Based on Ferrocenyl-Containing Polysiloxanes

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Animals such as chameleons change their skin colour in case of potential threat and recover damaged tissues [1]. Some ferrocenyl-containing polymers are similar to chameleon skin in terms of its colour-changing behaviour. For instance, they exhibit electrochromic properties due to easy reversible one-electron redox transition [2].

Another feature of chameleons represented in polymer materials is their self-healing ability. One of the most promising self-healing materials is silicone rubber [3]. Some silicone materials possess self-healing properties achieved through siloxane equilibrium. This mechanism is based on reversible interactions between "living" anionic centres and polysiloxane chains [2].

The siloxane equilibrium discussed above allowed us to prepare unique chameleon-like ferrocenyl-containing silicone rubbers (FSRs) which exhibit both electrochromic and self-healing properties [**?**]. Thus, FSRs were obtained through ring-opening anionic copolymerisation of cyclic siloxane monomers including octamethylcyclotetrasiloxane (D_4), tetraferrocenyl-substituted cyclotetrasiloxane (1,3,5,7-(2-ferrocenylethyl)-1,3,5,7-tetramethylcyclotetrasiloxane, Fc_4D_4), and bicyclic cross-linking agent (bis-D_4). The physicochemical properties of the FSRs were estimated by tensile tests and cyclic voltammetry. As a result, the tensile strength of the FSRs reached 0.1 MPa, and elongation at break was 215%. After one hour, the recovery of FSR self-healing efficiency at 25 and 100 °C reached 98%. The FSRs also possess redox activity (Fc/Fc^+ transformations at E^0 = 0.43 V) and electrical conductivity at the level of antistatic materials (approximately 10^{-10} S cm^{-1}). The FSR films change their colour from yellow (reduced state) to blue (oxidised state). Our chameleon-inspired materials could find potential application as redox-active and flexible electrochromic coatings.

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sciforum-086145: Evaluation of the In Vitro Anti-Inflammatory Potential of Biogenically Synthesized Silver/Silver Oxide Nanoparticles Utilizing Pumpkin Agricultural Byproducts

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The abundant bioactive compounds and anti-inflammatory metabolites in pumpkins have prompted increasing research interest in utilizing cucurbit residues to derive in vitro anti-inflammatory agents. The present study investigates and compares the anti-inflammatory potential of Ag/Ag_2O nanoparticles (NPs) synthesized using pumpkin peels (PPs), seeds (PSs), and leaves (PLs). Ag/Ag_2O NPs were synthesized using the aqueous extracts of pumpkin byproducts under varying conditions, including different concentrations of $AgNO_3$, varying extract-to-ion solution ratios, differing irradiation methods (solar, microwave, UV, etc.), and varied incubation times. Biosynthesized Ag/Ag_2O NPs were characterized via UV–visible spectrophotometry, FTIR, SEM, TEM, and XRD analysis. Anti-inflammatory activity was assessed through egg albumin denaturation and human red blood cell membrane stabilization assays. The activity was compared to standard anti-inflammatory drugs ibuprofen and aspirin (100–1000 ppm). The biogenic Ag/Ag_2O NPs synthesized under optimum conditions exhibited characteristic surface plasmon resonance peaks ranging from 436 to 450 nm in UV-vis spectrophotometry, confirming NP formation. FTIR spectroscopy revealed the functional groups in the plant extracts involved in NP synthesis. SEM imaging showed the agglomerated spherical morphologies of the NPs. TEM analysis indicated particle sizes ranging from 7 to 10 nm. XRD patterns confirmed the face-centered cubic crystalline structure of Ag/Ag_2O NPs. The PP-mediated Ag/Ag_2O NPs exhibited significantly higher (p0.05) anti-inflammatory activity compared to ibuprofen in the egg albumin denaturation assay, with IC_{50} values of 478 ppm and 598 ppm, respectively, while the PL-mediated Ag/Ag_2O NPs demonstrated significantly higher membrane stabilization activity compared to aspirin, with IC_{50} values of 419 ppm and 452 μg/mL, respectively. In both assays, the anti-inflammatory activity of the plant extracts alone was very low compared to Ag/Ag_2O NPs. The biomimetic approach showed that biosynthesized Ag/Ag_2O NPs exhibited enhanced anti-inflammatory effects, demonstrating promise as novel anti-inflammatory agents with the potential sustainable production of nanotherapeutics.

sciforum-089571: Fish Scale-Inspired Stab-Resistant Body Armour

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While commercially available lightweight "stab-proof" apparel exists, these offer little resistance to true stabbing as they are primarily designed to withstand slash attacks. Yet, crimes involving the use of a knife or sharp instrument have consistently been rising in the UK over the course of several decades. For the most part, the various proposed solutions to stab-proofing are based on speciality textiles, and while these have shown success in slash-proofing, their utility for stab-proofing is still somewhat unknown. Nature showcases a plethora of puncture-resisting materials and structures. At the macroscale, these include carapaces, egg cases, toughened skin, and more. One of the most effective protective mechanisms known comes through surface scaling, present on animals such as reptiles and fish. Scaled protective armours present in extant fish species include overlapping elasmoid scales, interlocking ganoid scales, placoid scales, tessellating carapace scutes, and interlocking plates. Here, we research overlapping and interlocking scaled structures to ascertain the stab penetration resistance of biomimetic scaled structures against continuum material. We use additive manufacturing methods to manufacture biomimetic armour made of nylon, a common protective artificial material used in slash-proofing textiles. Stab-testing the HOSBD body armour standard 2017, we find that biomimetic scales made of nylon offer greater protection against direct stabbing, than continuum nylon material sheets do. This can be attributed to (a) heightened flexibility in an interlocked fish scale structure that does not exist in a continuum sheet of the same material and (b) the effect of the fish scales overlapping, resulting in a greater penetration depth requirement before the structure undergoes perforation.

sciforum-089359: Flexural Enhancement in Beetle-Inspired Sandwich Plates with a Large Height-to-Thickness Ratio Core

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This study investigates the flexural mechanical properties of aluminum middle-trabecular beetle elytron plates ($MBEP_N$) with a significant height-to-thickness ratio core to understand how varying numbers of trabeculae (N) influence their bending resistance.

Introduction

Inspired by the natural world's engineering marvels, this study delves into the biomimetics of materials and structures, focusing on the remarkable structural mimicry of beetle elytron plates. Beetles, among Earth's most ancient organisms, have evolved lightweight yet robust elytra that conceal secrets of structural efficiency and durability. Mimicking the beetle elytron, we explore its analogous sandwich structure, akin to man-made aircraft wings, and its core's unique configuration—a honeycomb network reinforced with strategically placed trabeculae. This bio-inspired approach not only pays homage to the beetle's evolutionary refinement but also seeks to harness these natural designs for advanced engineering applications, embodying the essence of biomimetics in materials and structures.

Methods

This study employed a two-fold approach: quasi-static three-point bending tests on traditional honeycomb plates ($MBEP_0$) and bio-inspired $MBEP_2$ plates, followed by finite element analysis for MBEP variants (N = 2, 4, 6).

Results

$MBEP_2$ exhibited a notable 41.4% increase in flexural strength over traditional honeycomb plates. Contrary to expectations, higher N did not correspond to improved bending performance; instead, $MBEP_2$ outperformed others, including $MBEP_6$, with a distinct upward plateau on the load-displacement curve. Weak bending resistance was particularly noted near the upper plate of the first honeycomb wall across configurations, with deformation patterns varying with N. These findings suggest a complex relationship between trabeculae quantity and flexural performance, challenging simple linear assumptions.

Conclusions

This research uncovers previously unknown aspects of MBEP's flexural performance, highlighting its potential for engineering applications. The variation in trabeculae numbers and distributions offers insights into optimizing the material's mechanical properties for broader utilization in design and manufacturing.

sciforum-086670: Harmonizing Nature, Engineering, and Creativity: An Interdisciplinary Exploration of Engineered Living Materials, Artistry, and Sustainability in Collaborative Mycelium Brick Construction

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This study presents an innovative approach to interdisciplinary education by integrating principles of biology, engineering, and art to foster holistic learning experiences for children. The focus lies in assembling mycelium bricks as engineered living materials with promising applications in sustainable construction. Through a collaborative group task, children engage in the hands-on creation of these bricks, gaining insights into mycology, biomaterials engineering, and artistic expression. The curriculum introduces fundamental concepts of mycelial growth and its potential in sustainable material development. Children actively participate in fabricating 3D forms (negative and positive) using mycelium bricks, thereby gaining practical knowledge in shaping and moulding living materials. This hands-on experience enhances their understanding of biological processes and cultivates an appreciation for sustainable design principles. The group task encourages teamwork, problem solving, and creativity as children collaboratively compose structures using mycelium bricks. Integrating art into the activity adds a creative dimension, allowing participants to explore aesthetic aspects while reinforcing the project's interdisciplinary nature. Conversations about the material's end of life and decomposition are framed within the broader context of nature's cycles, facilitating an understanding of sustainability. This interdisciplinary pedagogical approach provides a model for educators seeking to integrate diverse fields of knowledge into a cohesive and engaging learning experience. The study contributes to the emerging field of biomimetics education, illustrating the potential of integrating living materials and 3D understanding activities to nurture a holistic understanding of science, engineering, and artistic expression in young learners.

sciforum-088337: Image Analysis of Butterfly Wing Surfaces for the Creation of New Biomimetic Materials

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Introduction

The biological structures of different butterfly wings were examined in terms of the analysis of their surfaces. Insect wing structures are corrugated surfaces with different characteristics and represent completely different types of corrugations.

Methods

As part of this research study, image analysis of the mentioned surfaces was performed. The structures were first characterized by a scanning electron microscope (SEM), and then analyzed in the ImageJ program.

Results

Various characteristics were assessed, such as the repeatability of pattern within the surface of the structures, the filling of the surface, and the shape and behavior of the corrugation. Such tests are important for the design of biomimetic artificial materials for various applications. In this way, we can fully define the material and study its behavior, and then adapt it to the production needs. The results proved to be very significant for the adaptation of structure types in military applications.

Conclusion

The use of such designed materials with different corrugations is important for military applications because such materials show great sensitivity to the radiation of different wavelengths of light. The combination of materials science and military application is currently a promising technological field; therefore, this kind of research can further produce very important results.

sciforum-089912: Low-Velocity Impact Behaviour of Biomimetic Cornstalk-Inspired Lightweight Structures

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This study delves into the investigation of dynamic response and energy absorption capabilities inherent in cornstalk-inspired porous structures. The specimens were meticulously fabricated using acrylonitrile butadiene styrene (ABS), a material chosen for its known toughness and impact resistance, through 3D printing. Characterization of the base material was conducted using Shimadzu® Universal Testing Machine and Split Hopkinson Pressure Bar. Low-velocity impact tests were subsequently executed, subjecting the structures to a dynamic strain rate of 3.04×10^2 s^{-1}. In-depth damage analyses were carried out using scanning electron microscopy (SEM) to understand the brittle behaviour of polymers and identify debonding in the 3D-printed layers.

The results unveiled a noteworthy 12% increase in specific energy absorption (SEA) compared with quasi-static measurements. Remarkably, the selected topology exhibited outstanding energy-absorbing capability, surpassing that of many other porous structures reported in the literature by approximately ~17.5%. Complementary numerical modeling of compressive dynamic loading was performed to reinforce our experimental findings. This research not only validates the promising potential of cornstalk-inspired structures for enhanced energy absorption but also suggests avenues for improvement through the optimization of geometrical design. Importantly, this work builds upon the author's prior exploration of the quasi-static response of the cornstalk-inspired design, providing a comprehensive and nuanced understanding of the material's dynamic behaviour.

sciforum-086712: Mechanical Intelligence in Insect Wings: The Role of the Basal Complex in Wing Shape-Morphing

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The flight muscles of birds and bats actively control wing deformations, while insect wings rely mainly on passive mechanisms determined by their adaptive wing structures. This study delves into the unique design of insect wings, specifically focusing on the 3D component known as the basal complex situated in the wing's proximal region. Our research, employing a comprehensive array of multidisciplinary methods, including modern imaging techniques, mechanical testing, finite element analysis, parametric modelling, conceptual design, and 3D printing, rigorously tests the hypothesis that the basal complex plays a pivotal role in determining the quality and quantity of wing deformations during flight. The results support this hypothesis, revealing that variations in the basal complex's material and structural design elements among dragonfly and damselfly species lead to significant differences in symmetric or asymmetric deformation patterns observed in insect wings in flight. Our systematic investigation of geometric parameters in a set of numerical models further indicates adaptations for achieving maximum camber under loading. Inspired by the basal complex, we introduce a shape-morphing mechanism applicable to wind turbine blades, simplifying actuation and control systems. This research not only contributes to understanding the biomechanics of complex insect wings but also offers valuable insights for engineering shape-morphing systems with enhanced mechanical intelligence and simplified control requirements.

sciforum-086734: Mimicking the Dynamic Mechanical ECM Using Engineered Biomaterials to Investigate Cellular Crosstalk

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Introduction

The stiffness of a tissue changes during the lifetime of an individual and is an indicator of age, disease, and pathophysiological conditions. Increased tissue stiffness is a hallmark of illnesses like cancer and cardiovascular diseases, causing major mortality worldwide. Cells interact with the mechanical cues of the surrounding ECM by adjusting themselves through communication from the nanometer to the meter scale by rearranging their cytoskeleton, nuclear envelope structure and composition, and migration. Understanding how forces work will unlock new avenues in disease research, regenerative medicine, and the design of implantable biomaterials.

Materials and methods

A 3D silk fibroin biomaterial library is created with diverse mechanical stiffness ranging from ~3 kPa to 0.4 kPa.

Results

The cell–cell and cell–ECM interactions in this dynamic niche are evaluated using stem cells. The up- or down-regulation of certain genes with ECM stiffness acts as a marker of cellular response to dynamic mechanical ECM, while cell-mediated mineralization is indicative of cell–cell and cell–ECM crosstalk.

Conclusion

This study also confirms that biomimetic, dynamic ECM-mediated physical cues not only influence the differentiation behavior of the cells but also regulate the migration of surrounding cells toward the engineered niche. However, further investigation is needed.

Acknowledgments

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sciforum-089591: Monometallic and Bimetallic Platinum-Containing Nanoclusters for Biomedical Applications

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Nanosized materials with small diameters are known to be excellent for various applications such as catalysis, the sensing of biologically active species, and imaging, or for their anti-oxidant and anti-bacterial activity [1]. Noble metal nanoclusters (NCs) consisting of several atoms have been gaining much attention as novel fluorescent markers owing to their optical properties, which include their size-dependent emission wavelength. In the present study, we use the green synthesis of monometallic and bimetallic nanostructures with bovine serum albumin serving as a template, similarly to one of our previous works [2]. We have investigate the behavior of platinum-containing nanosystems generated by different reducing agents, varying the reactant molar ratios, varying the synthesis approach, and introducing the second metal. Pt NCs show fluorescence emission peak in the range of 450–470 nm (370 nm excitation wavelength). Different molar ratios of the reactants have been used to optimize the fluorescent properties of monometallic and bimetallic Pt-containing NCs. The change in the reactants' molar ratios affected the fluorescence intensity and position of the fluorescence emission maximum. Other factors affecting the fluorescent characteristics of these metallic NCs are still under investigation. The as-prepared luminescent NCs can be utilized as contrast agents and/or biomarkers, which is going to be tested in the near future. Moreover, they could play a role in catalytic activity and biosensing, as known from the literature [3].

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sciforum-086742: Nanofiber-Based Biomimetic Scaffolds for Intervertebral Disc Tissue Repair

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Introduction

The most common back and neck discomfort is closely linked to the dysfunction of intervertebral discs (IVDs) as they undergo degeneration. Intervertebral discs (IVDs) are composed of three distinct structures, namely the nucleus pulposus (NP), the annulus fibrosus (AF), and vertebral end-plates (VEP). With advancing age, there is a decrease in the water content of the NP, resulting in the accumulation of mechanical loads on the annulus. Consequently, the NP experiences wear and cracking, leading to an ensuing inflammatory reaction and the occurrence of a prolapsed intervertebral disc.

Methods

Current therapeutic approaches for degenerative disc disease provide pain relief or partially restore the native functions of IVDs. The application of biomimetic materials in tissue engineering represents a new strategy to restore the structure and function of IVDs. Nanofiber scaffolds are widely utilized in the engineering of soft orthopedic tissues such as intervertebral discs due to their extensive surface area, structural similarities to components of the extracellular matrix, capacity to deliver bioactive signals, flexibility in polymer selection, and cost-effective fabrication methods. Fabricated IVDs must simulate the structure of native discs. Long-term implantation should show good shape maintenance, hydration, integration with surrounding tissues, and mechanical support and flexibility.

Results and Conclusions

Biodegradable nanofibers can carry anti-inflammatory drugs and cytokines for gradual release, aiding in healing and preventing inflammation. Synthetic scaffolds loaded with bioactive materials, stem cells, and growth factors can support IVDs for long-term cure. The use of natural materials like silk with textile design features can imitate IVD structure, providing cytocompatibility, biodegradability, high strength, and stiffness in tension and compression. Nanofiber-based scaffolds, with their extraordinary properties, provide researchers with the opportunity to design scaffolds that can mimic the morphological and mechanical properties of native IVDs.

sciforum-086685: New Concepts in Bioinspired Engineering from Extracted Tree Root Principles

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Tree root systems are multifunctional plant elements that could serve as biomimetic role models for anchoring and supply systems in engineering. A previous study has established an analogy framework for the design of building foundations and coastal resilience. Due to their underground existence, research on root morphology is largely based on time-consuming and tedious manual or semi-automated processes.

In a reverse biomimetic approach, the methods of photogrammetry and parametric design were applied to the morphological analysis of coarse tree root systems, and gradually refined to produce 3D models to reliably extract design principles. Ten different root specimens across four different tree species were imaged in the field and reconstructed virtually through photogrammetry. A parametric algorithm then analyzed the generated 3D models and extracted their skeleton to access the system's topology and morphological traits (such as volume, surface area, radius, curvature, and branching angles).

Topological information together with traits provide information about biological diversity across species and allow for the identification of key strategies for root performance in specific environments. Based on the abstracted design principles, functional transfer to the conceptual design of novel bio-inspired infrastructure is carried out.

For the applicability of basic root design principles, such as the number of branches and branching angle, to the function of anchoring, a pull-out study in a granular medium was carried out. Further conceptual proposals for the design of geotechnical infrastructure based on the biological traits are currently under development. Such exploratory studies serve to develop the potential and applicability of root-inspired infrastructure.

sciforum-089630: Optimization of Bioinspired Scaffolds to Enhance Cell Viability and Enable Tissue Growth

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The construction of artificial biological tissues presents complex interdisciplinary challenges, requiring the convergence of knowledge from materials science, biophysics, biology, design, and related fields. The interaction between cells and the extracellular matrix (ECM) plays a crucial role in mechanobiological responses, where the tissue structure influences tissue guidance and growth. Additionally, it is important to consider the influence of various factors, such as porosity, surface topography, chemical composition, and cellular interactions, on scaffold efficacy. In this context, tissue-mimicking is of paramount importance, as it provides adequate and functional support for tissue growth, as well as enhancing cell viability rates. This study aimed to evaluate the influence of scaffold structure on the growth of biological tissues, in order to optimize their growth. Via computational models, tissue growth and its mechanical stiffness behavior can be simulated. It is expected that advances in scaffold research will lead to more sophisticated and effective tissue engineering technologies capable of promoting the regeneration of damaged or lost tissues more precisely and efficiently. The strides made in scaffold research hold substantial promise for the development of advanced tissue engineering technologies adept at effectively regenerating damaged tissues. This progress is poised to bring about profound implications for regenerative medicine, ushering in a new era of innovative therapeutic approaches to address diverse medical conditions. As such, these advancements offer not only hope for enhanced patient outcomes but also the potential for transformative breakthroughs in the field of healthcare.

sciforum-089574: Predicting the Flexural Modulus of Variable-Pitch-Angle, Porous-Bouligand-Structured 3D-Printed Polymer

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Many natural structures, while being lightweight and porous, exhibit respectable levels of stiffness. Natural structural designs are complex and hierarchical, and with the surge in societal demand for lighter weight, durable, yet resilient materials, there is a concurrent research need to consider biomimetic materials as alternatives to traditional materials since these can be manufactured more easily now than ever before, with significant advancements made in the area of digital design and manufacture. Our study considered porous Bouligand structures, which are structures built up of twisting fibrous architecture, but with spaces set between the fibres which induce porosity into the structure. These are more complicated than non-porous Bouligand structures, since the addition of porosity into the material creates a secondary variable besides fibre pitch. As such, there is currently no analytical model available to predict the modulus of such materials.

Our paper explores the correlation between porosity, polymer fibre pitch angle, and flexural modulus in porous-Bouligand-structured polymers. Our structures were digitally manufactured using SLA additive manufacturing methods, after which they were subjected to three-point bending tests. Our aim was to simply and parametrically develop an analytical model that would capture the influences of both porosity and polymer fibre pitch angle on the flexural modulus of the material.

Our model is shown below and we derive this by applying non-linear regression to our experimental data.

$$E_f = E_{poro}\ (a{\theta^3}_f + b{\theta^2}_f + c\theta_f + d)$$

This model predicts the flexural modulus, E_f, of porous-Bouligand-structured polymer as a function of both porosity and pitch angle. Here, E_{poro} is a linear reduction of the modulus as a function of increasing porosity and is defined as the solid material modulus, E_{solid}, multiplied by porosity, φ, while θ_f signifies the polymer fiber pitch angle. This relationship is relatively accurate within the range of $10^\circ \leq \theta_f \leq 50^\circ$ and for porosity values in the range $0.277 \leq \varphi \leq 0.356$, as supported by our evidence to date.

sciforum-086662: Recycling Used Textile Waste to Achieve Biomimicry and Promote Circular Economy

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The textile business is one of the fastest-growing in the world, with items often only being worn seven times before ending up in landfills; it ranks sixth globally in terms of waste production. Biomimetics has a long relationship with silk, extending back more than two millennia. This research adopts a multifaceted approach to the circular economy concept, focusing on enhancing textile sorting procedures, devising recycling plans, and prolonging clothing lifespans. With the rise in popularity of the circular economy, more people are beginning to understand the significance of switching from the linear to the circular economic model. To encourage the growth of the circular economic model, several new legislations have been implemented. Many companies have a tendency to recycle their trash and turn it into clothing that is either of poorer quality or that may be raised to the same level with the application of chemicals and significant financial expenditure. The potential of a circular economy for the environment and a multibillion dollar business is examined in this article along with sustainable design approaches that minimise waste. It assesses how much room there is for collaboration in design and manufacturing within the fashion industry. With an emphasis on the expanding field of interdisciplinary textile research, this study examines the possibility of developing a mutually beneficial partnership between industry and academia, especially in the fashion sector, to advance sustainable practices. The purpose of this research paper is to start a conversation on biomimetic practices of the future in the built environment, specifically in relation to sustainability and transformative change. Rethinking manufacturing, maximising the reuse of textile products, adopting reproduction and recycling tactics, redistributing textiles to new markets, and refining techniques to prolong their lifespan are all recommended under this approach.

sciforum-086667: Sea Slag-Inspired Modification of Carbon Nanoparticles

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It is well known that some living organisms use different adaptation mechanisms to survive and thrive [1]. One of the outstanding examples of adaptation are marine gastropod mollusks *Elysia marginata* and *Elysia atroviridis* (sea slags) [2]. After being decapitated, these living organisms have an ability not only to survive but also to revive and grow again. These invertebrates inspire us to conduct a modification of carbon nanoparticles (CNPs) containing Csp^2-hybridized carbons using cyclooligosiloxanes containing redox-active metallocenes. In the CNP modification, the cyclooligosiloxanes containing redox-active metallocenes at first lose some of their parts (cyclopentadienyl ring) in the presence of the catalytic mixture, and coordinate to a wall of CNPs. Then, these cyclooligosiloxanes undergo cationic ring opening polymerization catalysis by one of the components of the catalytic mixture, and a polysiloxane chain grows.

The successful modification of CNPs using (poly)siloxanes containing redox-active metallocenes was confirmed by means of Raman and X-Ray photoelectron spectroscopies and transmission electron microscopy. The modified CNPs have good compatibility with the polysiloxane matrix and an improved distribution in it.

In this mollusk-inspired modification of CNPs, along with the grafting of the polysiloxane chain on the surface of carbon nanotubes, we introduced redox-active centers on the surface of the CNPs. This, in turn, significantly broadened the application of the modified CNPs as promising components of electrochemical sensors, biosensors [3] and energy storage devices [4].

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sciforum-089539: Study of the Effect of Synthesis Conditions on the Structural Properties of Biomimetic Polysaccharide-Templated Mesoporous Silica

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In our work, we chose chitosan (polysaccharide) as a template for the synthesis of mesoporous silica-based material (ZChM). Both acidic and slightly alkaline synthesis conditions were tested. In the acidic method, we varied the molecular weight of chitosan (200 and 500 Da) and the time of TEOS addition.

Biomimetic silica samples (ZChM-series) were characterized using TEM, XRD, BET, and TG/DTA methods. According to the obtained data, a material with a more ordered structure was achieved by using an acidic type of synthesis with chitosan 200 Da and a controlled rate of TEOS addition. This material has a surface area of around 790 m2/g, which is only is 30% less than the surface area of MCM-41-type materials. The material synthesized in alkaline conditions has a significantly lower specific surface area. In addition to the surface area, the synthesis conditions also affected the pore size of the resulting materials—the material obtained under alkaline conditions has the largest pore diameter (6,64 nm), while the second sample synthesized in an acidic environment (ZChM-2a) has a slightly lower pore diameter than MCM-41, 2.73 vs. 3.3 nm, respectively.

The new bioinspired silica samples were tested as adsorbents of water-soluble amino acids, and both kinetics and adsorption equilibrium were studied. It was found that synthesis conditions can significantly affect the sorption properties of mesoporous silica. The biomimetic silica synthesized with chitosan as a template in an acidic medium (ZChM-1a) can sorb tryptophan and phenylalanine. Otherwise, material ZChM-1s (synthesized in an alkaline medium) does not practically sorb these amino acids.

Thus, chitosan can be successfully used as a template for the synthesis of mesoporous silica. By varying the medium conditions, the molecular weight of chitosan, and the rate of addition of TEOS, it is possible to obtain mesoporous materials with different surface and adsorption properties.

sciforum-086265: Study on the Mechanical Properties and Energy Absorption Characteristics of Bionic Variable-Amplitude TPMS Structures

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Introduction

The three-period minimal surface (TPMS) structure has great potential in the fields of lightweight and energy absorption due to its high strength, high porosity, and self-supporting characteristics. However, previous studies have predominantly focused on aspects such as wall thickness, unit cell size, periodicity, and level set values. The impact of amplitude factors on the topological shape and mechanical properties of TPMS structures has not been fully elucidated.

Methods

Inspired by the amplitude characteristics of cuttlefish bone structure, this paper proposes a design method of TPMS structures with variable amplitude. Firstly, taking the classical Primitive, Gyroid, and Diamond structures as the research objects, the influence of amplitude on the topological morphology and relative density of TPMS structures was analyzed using the parametric method. Subsequently, the quasi-static compressive mechanical properties and energy absorption capacity of the Gyroid structure were studied through experiments and numerical simulations.

Results

The change in the amplitude led to a significant change in the topological morphology of the structure, but the maximum relative density of the structure only changed by 1.5%. The deformation modes of Gyroid structures of different amplitudes were identical, but as amplitude increased, mechanical properties and energy absorption capacity such as elastic modulus, yield strength and specific energy absorption increased.

Conclusions

The results indicated that the amplitude change has little effect on the relative density and deformation mode of the TPMS structure, but it can significantly regulate the mechanical properties of the structure on a large scale. With an increase in the amplitude factor, the densification strain of the structure slightly decreased, while the energy absorption capacity increased significantly. The research content can guide the design for the development of tissue scaffolds or energy-absorbing devices.

sciforum-086304: Synthesis and Characterization of Novel Selenated Hydrogels for the Treatment of Chronic Wounds

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A wound is a defect or break in the skin caused by physical or thermal damage. Depending on the area of skin affected, there may be a series of alterations in the organism, such as blood loss, dehydration, difficulty in maintaining body temperature, or infection. The wound healing process represents a complex series of biological events to restore the skin barrier function. Numerous studies have shown that low levels of reactive oxygen species (ROS) promote normal wound healing by stimulating cell migration and angiogenesis, but excessive ROS can derive in chronic wounds. In chronic wounds, a sustained inflammatory response leads to a large accumulation of ROS, which exceeds the physiological antioxidant capacity, impeding cell migration and proliferation and thus preventing tissue remodelling. It has been shown that antioxidants can accelerate wound healing, especially for chronic wounds. In this study, we developed a hydrogel based on a natural polymer and modified with selenium to add antioxidant and antimicrobial properties. The synthesis reaction has been confirmed with NMR and atomic absorption spectroscopy. The mechanical properties of the hydrogel were characterized by rheological tests. Viability assays were performed with human dermal fibroblasts. Hence, we developed an antioxidant and antimicrobial hydrogel with good biocompatible properties, which seems to be a promising therapy for the treatment of chronic wounds.

sciforum-089544: Towards Improved Remineralization: Calcium Ion incorporation Into Enamel Induced Using Aspartic Acid In Vitro

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Tooth enamel, vulnerable to various harmful factors, often undergoes demineralization. Combating enamel destruction typically involves replenishing demineralized areas with non-native calcium sources, which poses challenges for effective remineralization. Aspartic acid (Asp) can participate in the crystallization process of hydroxyapatite, improving its structural order and thereby helping to restore and strengthen enamel. The aim of the investigations was to determine the effect of Asp on the remineralization of a bovine enamel block in vitro. Enamel blocks were sectioned from bovine teeth, and the baseline surface microhardness (SMHR) of the samples was measured. After demineralization in a solution at pH 4.5 for 60 min, SMHR was remeasured. Ten enamel samples per group were treated with respective solutions for 16 h at pH 6.5. The percentage of SMHR achieved through the treatments was calculated and used to compare the ability to repair demineralized enamel samples. Three investigations with the same design were conducted. The initial experiment indicated that 1% hydroxyapatite facilitated enamel remineralization, achieving a significant mean increase in surface microhardness (22.99 $\pm$ 10.43; p0.05) compared with that of the negative control, deionized water, which showed a mean decrease (-1.87 ± 17.11; p0.05). However, this remineralization was not superior to that induced by the fluoride positive control (35.56 $\pm$ 23.41; p0.05). Subsequently, the second experiment established that 0.5% aspartic acid significantly reduced enamel microhardness (-37.32 ± 24.64; p0.05), indicating a pronounced demineralizing effect when compared with both deionized water (-17.52 ± 23.54; p0.05) and fluoride (14.12 $\pm$ 13.40; p0.05). The third experiment demonstrated that the combination of 0.5% aspartic acid with 1% hydroxyapatite significantly enhanced remineralization (33.08 $\pm$ 14.84; p0.05), outperforming the fluoride-positive control (5.15 $\pm$ 4.84; p0.05) as well as deionized water (-29.21 ± 18.38; p0.05). In conclusion, while aspartic acid alone may lead to enamel demineralization, its combination with hydroxyapatite shows promise in surpassing fluoride's remineralizing efficacy, highlighting a potential synergistic approach for dental treatments.

sciforum-086665: Transformational Potential of Urbanization Based on Biomimicry Notions

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One avenue for creating climate adaptation that has not yet been investigated is the urbanization process. Using ideas from nature seems to be a viable strategy for cities facing this problem. Investigating whether biomimicry concepts may enhance urban settings is the focus of this abstract. Long-term sustainability is promised by the creation of materials and structures that mimic nature and natural processes, in addition to addressing climate adaption. Natural disasters may be addressed more effectively with the use of biomimicry, which draws inspiration from biological processes and aims to prolong civilizations. In addition, a number of contemporary biomimetic solutions will be examined, along with their impacts, including structural organizsation inspired by honeycombs, batteries inspired by electric eels, spiders as a source of silk, and gecko stickiness in adhesive techniques. In addition to promoting sustainability, examining these tried-and-true natural solutions enhances the robustness and efficiency of engineered materials and buildings. By combining interdisciplinary research and a literature review, this study uncovers the untapped potential of biomimicry and urban evolution to provide adaptable solutions that align with the equilibrium of natural ecosystems. As cities grow and adapt to these obstacles, incorporating biomimicry into materials and buildings is a key but understudied characteristic. Urbanization's revolutionary potential based on biomimicry principles is highlighted in this abstract, laying the groundwork for future research.

Abstracts

Session 2. Biomimetic Design, Constructions and Devices

sciforum-089548: Assessment of Biological Carbonation Strategies in the Marine Ecosystem and Potential Applications in Cementitious-Based Products via a Biomimetic Model

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The increase in the concentration of greenhouse gases of anthropogenic origin, especially carbon dioxide, concerns different spheres of society. In light of this, efforts, such as carbon capture and utilization, are being made to ensure the temperature addition limit of 1.5 °C is not exceeded by 2100. Within this scenario, the construction sector presents itself critically, especially due to cement, which accounts for between 7% and 8% of global carbon dioxide emissions. It is known that during the life cycle of cementitious materials, a natural carbonation process occurs, where CO2 is reincorporated into the cementitious matrix. Thus, this study sought to investigate the biological processes related to carbon capture and utilization for structural consolidation in order to assimilate the strategies applied in nature. It also sought to assess the viability of replication in artificial processes as a mechanism for enhancing the carbonation that occurs in the life cycle of cementitious materials, incorporating environmental intelligence to address environmental and urban challenges. A literature review confirmed the potential benefit of carbon capture, utilization, and storage inspired by the biomineralization process, and this can be observed in the marine ecosystem. Additionally, the relevance of oceans as a source of knowledge for the development of new solutions is highlighted. As an additional contribution of the study, the detailed process of biomimetic thinking presented throughout the discussion is highlighted, emphasizing the multidisciplinary scope necessary to ensure the understanding of design strategies.

sciforum-086295: Contact Behaviours of Biomimetic Spatula-Shaped Adhesive Microstructures on Rough Surfaces Using Finite Element Simulations

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During biological evolution, numerous organisms have developed hair-like attachment structures to achieve stable adhesion on diverse surfaces. This has inspired researchers to explore biomimetic adhesive microstructures, wherein mushroom-shaped structures have received extensive attention, while spatula-shaped ones better suited for adhesion on rough surfaces have received comparatively less. Here, we present two bio-inspired adhesive prototypes, both featuring an inclined seta and spatulate tip. One prototype incorporates a variable cross-section cylinder with a leaflike thin plate, while the other comprises a uniform cross-section square column and a wedge thick plate, exhibiting geometric transition at the seta-tip joint. Finite element analysis is utilized to investigate the adhesive contact behaviours of these prototypes under vertical displacement on surfaces with varying roughness, specifically asperity radii of 30 nm, 1 μm and infinity (flat surface). The results reveal that compared to the surface with a 30 nm radius asperity, the spatula could adapt relatively well to the single asperity with a 1 μm radius due to such asymmetric structures, which also lead to a leverage phenomenon that will compete with adhesive forces and encourage the contact surfaces to separate. Although the thicker spatula tip exhibits poor flexibility, resulting in reduced effective contact area and adhesion, it may allow the regulation of attachment under unidirectional loading. This study contributes novel insights into the contact behaviour of spatula-shaped adhesive structures and provides valuable inspiration for the future development of artificial adhesives.

sciforum-086681: Performance of Fish Scale-Inspired Armor under Impact Loading by Different Impactor Shapes: A Numerical Investigation

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Fish scale-inspired armor exhibits numerous advantages over conventional armor plates. This study includes hybrid scale-tissue design with scales inclined at a certain angle. The fish scale-inspired design had a curved radius of 200 mm, a length of 19 mm, a width of 12 mm and an inclination of 10°. The total size of the specimen measured 80 mm × 80 mm × 10 mm. The acrylonitrile butadiene styrene (ABS) material represented the hard scales, while thermoplastic polyurethane (TPU) mimicked the soft tissue. Low-velocity impact scenarios were investigated using the commercially available software LS-Dyna. Scales/ABS were modeled using a plastic kinematic (MAT03) material model, while the tissue/TPU were modeled using a plasticity polymer (MAT89). The effects of indenter shape (hemispherical, conical, and flat head) were studied at an impact energy and velocity of 100 J and 6 m/s. During the impact process, all impactors fully perforated the sample. The performance of the specimen was evaluated based on the specific energy absorption and damage area. The pecific energy absorbed by the conical indenter was the largest, followed by the hemispherical indenter. The bio-inspired specimens resisted the flat indenter early on, while elastic resistance on other indenters gradually increased in the elastic region. The peak forces absorbed by the hemispherical, conical and flat head indenters were 6.1 kN, 5.4 kN and 3.7 kN, respectively. The primary failure modes were shear failure and the tensile breaking of the scales. The present study highlighted the effect of indenter shape on the impact behavior of fish-scale inspired design.

sciforum-082994: Research on Urban Micro-Community Planning and Design Inspired by Functional Properties of Analogous Cells

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As the basic unit of life, analogous cells possess efficient spatial utilization, material exchange, and information transmission characteristics which provide important insights for micro-community planning and design. Based on three functional attributes (the spatial utilization performance, material exchange, and information transmission of analogous cells), this study proposes planning and design principles and methods for micro-community inspired by the functional properties of analogous cells. In response to the efficient spatial utilization characteristics of analogous cells, this study proposes the design principles of compact communities. By reasonably arranging community spaces, improving land use efficiency, and achieving maximum functional diversity within limited areas, this study introduces design methods, such as vertical greening and rooftop gardens, to increase community green space and improve residents' living environment. Drawing on the material exchange characteristics of analogous cells, this study focuses on enhancing community fluidity during the planning and design process. Specifically, it optimizes the road system, reduces the exposure time of motor vehicles in the community, and embeds low-carbon travel modes such as walking and cycling, thereby reducing air pollution in the micro-ecosystem. Inspired by the information transmission characteristics of analogous cells, this study focuses on connectivity and accessibility during the initial planning process. By reasonably planning public spaces and pedestrian networks, strengthening the connections between various parts of the community allows residents to conveniently and efficiently reach their destinations within a short period of time. This study conducts planning and design practices for a micro-community inspired by the functional properties of analogous cells, using a micro-community in Wuhan, China as an example. The results show that micro-community planning and design inspired by the functional properties of analogous cells can maximize micro-community functions, promoting the sustainable development and renewal of community functions.

sciforum-089578: Batteries and Biomimicry: Transitioning towards Structural and Systemic Design

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Introduction

The electrification of transport has made battery technology a focal point of research and development. However, conventional manufacturing and disposal methods involving toxic elements present several direct and indirect environmental implications. This research review proposes a biomimetic approach to transition from material-centric to structure- and ecosystem-based functionality across various scales in energy storage. This encompasses electrode fabrication, material functionalization, separators, charge–discharge transfer ecosystems, geometrical arrangements, and thermal regulation. Nature-inspired fundamental structures such as gradients, cellular, fibrous, and tubular configurations were specifically explored for electrode slurry and binder functionalities, while sutures and overlapping scales were investigated for cell design. Geobacter and its related microbial ecosystems were identified as potential ecosystems for bio-designing charge transfer.

Objective

By shifting the focus from chemical innovation to structural and systemic design, this study aims to advocate for the utilization of life-conducive energy materials and resilient cell architectures to eliminate the adverse environmental impacts associated with traditional battery manufacturing and disposal restrictions.

Methods and Results

The available scientific literature, frameworks, and tools related to nature-inspired energy storage technologies were reviewed and analyzed. A co-creative, frugal, and agile framework is proposed for integrating nature-inspired structures and ecosystems at various stages of cell and battery fabrication. Gaps in the literature, existing methodologies, and future directions concerning biomimetic batteries were identified.

sciforum-086547: Bioinspired Snapping-Claw Apparatus to Study Flow-Accelerated Corrosion of Low-Carbon Steel

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This research presents a novel mechanical device, inspired by the pistol shrimp snapper claw, featuring a controlled, periodic opening/closing motion that generates oscillating flows at transitional Reynolds numbers. An innovative method for determining the corrosion rate of carbon steel samples under oscillating acidic streams (an aqueous solution of HCl) is proposed. Very thin carbon steel specimens (25 microns thick), coated with Zn on one side and insulated from the stream, enable the electrochemical sensing of the Zn surface upon perforation. With the use of this technology and a 532 nm laser coupled with an optical fiber and video camera arrangement, corrosion may be effectively detected, enabling precise pit counting and location determination. Furthermore, this study explores the impact of hydrodynamic cavitation on the corrosion of low-carbon steel samples by using the mechanical device to imitate the fast closing of pistol shrimp claws. Current-time curves reveal significant changes linked to local variations in dissolved oxygen concentration, cavitation-induced erosion, and alterations in the nature of surface corrosion products. The methods suggested here open the door to the creation of alternative corrosion sensors that have appealing qualities such as low cost, small size, and reasonable precision in detecting localized damage in both space and time.

sciforum-086189: Biomimetic Hydrogel-Based Electronic Skin: An Overview Based on Patent Analysis

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Introduction

One major challenge for electronic skin (e-skin) is the need for soft and stretchable electronic materials, as conventional materials present limited functionality, low surface adhesion, and relatively high power consumption. The development of skin-like hydrogel devices introduces additional challenges, such as low ambient stability, because of their sensitivity to environmental conditions. Research and development are making progress in addressing these challenges, and there have been notable advancements in the field of biomimetic hydrogel-based e-skin. Innovations in this area have the potential to pay off. Organizations that invest in and develop innovative e-skin technologies based on biomimetic hydrogels can secure intellectual property rights through patents. In this regard, this work is dedicated to reviewing the state-of-the-art by presenting what has been patented in regards to biomimetic hydrogel-based e-skin.

Methods

Different patent databases were employed, utilizing diverse sets of keywords and associated terms. Searches were carried out based on patent titles, abstracts, and claims to ensure the comprehensive coverage and retrieval of relevant information. The search was then filtered regarding publication year, jurisdiction, and patent classifications.

Results

The inception of biomimetic hydrogel-based e-skin patenting can be precisely traced back to the earliest priority date, pinpointing 1988 as the commencement year. Notably, the zenith of patent document activity occurred in 2013 and 2021. Analysis reveals that the United States and China stand out as the most prolific nations in patenting biomimetic hydrogel-based e-skin. The majority of inventions pertaining to biomimetic hydrogel-based e-skin, specifically designed for hydrogels or hydrocolloids for use in prostheses or as coating chemical sensors, are distinguished by their functional attributes and physical properties.

Conclusions

This work, which offers a competitive analysis spanning trends in biomimetic hydrogel-based e-skin, provides several recommendations aimed at guiding the formulation of innovative research strategies.

sciforum-089629: Bridging Biomimetics and Additive Manufacturing for Dynamic Design Solutions

Silvia Titotto

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Due to the dynamic behaviours often present in biological environments, biomimetics encourages solutions that can address complex design challenges more effectively. From the conceptualization to the implementation of a product, there are several phases in which prototyping is the fastest way to address eventual inaccuracies in design translations from biological mechanisms. Prototyping is also used to improve the combination options of design and materials' specificities altogether. In most cases, additive manufacturing (AM) provides the necessary level of customization within a reasonable timeframe because they can be reprinted after adjustments in the parameters of the digital design. AM has revolutionized the fabrication process by constructing objects layer by layer through the precise deposition of materials. This approach enables meticulous control over dimensions and allows the tailored programming of properties in intricate printed objects. While traditional 3D printing produces static structures, the advent of 4D printing introduces dynamic capabilities, wherein printed objects exhibit shape-changing abilities over time in response to external stimuli, driven by passive energy mechanisms. This concept mirrors the natural phenomenon of self-assembly observed in living organisms, wherein disparate components are autonomously organized into structured forms to adapt to environmental challenges and optimize survival. Inspired by nature's biomechanics and adaptive systems, 4D printing technologies leverage insights from biological processes, paving the way for hybrid technologies that emphasize shape adaptability and responsiveness to stimuli. Interdisciplinary collaboration plays a crucial role in harnessing diverse expertise and fostering innovation at the intersection of multiple fields and sometimes within the same project, as top-down as well as bottom-up approaches are useful. This collaborative approach enables the conceptual process of mimicking relevant properties and incorporating mechanisms of the studied biological system into design applications that effectively respond to challenges rather than inaccurate bioinspired forms and shapes that mainly inspire curiosity.

sciforum-086739: Design and Development of Bio-Inspired Fixed-Wing Flying Robots

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Introduction

Low-Reynolds-number aerodynamics is important to a number of natural and man-made flyers. Currently, this is a topic under active study in the aerospace engineering community, motivated by interest in micro air vehicles (MAVs), and has been increasing rapidly. Our research suggests that it is more practical to employ bio-mimetic technology to utilize insect forms such as the dragonfly for specific functional parts of conventional robots only or to comprehensively refine existing engineering instead of directly imitating entire complex functions of living creatures.

Methods

Computational fluid dynamics (CFD) will be utilised to investigate the aerodynamic forces over corrugated and tandem wings. Once the results are verified and validated, finite element analysis (FEA) will then be used to study the effects of structural loading on the wings. Topology optimisation algorithms will then be used to design lightweight and load-bearable structural elements. The next phase of the project will involve building and flight-testing (indoor/outdoor) various prototypes of flying robots with an emphasis on material selection and construction techniques.

Results

This is an ongoing research project that was recently initiated. We are currently working on the CFD part by conducting studies on Reynolds number (Re) effects and angle of attack (AoA) to gain a better understanding of the benefits of tandem and corrugated wings in terms of flight stability and drag reduction. We are aiming to include the results from the FEA and topology optimisation studies in the upcoming conference.

Conclusion

Our research suggests that the majority of the work carried out on the design and development of flying robots focuses on the direct imitation of entire functions of living creatures. In this paper, we presented a more practical approach by employing biomimetics to utilise the dragonfly wing form and comprehensively refine the design of fixed-wing flying robots.

sciforum-089570: Diatom Frustule-Inspired Bridges: A Fusion of Art, Architecture and Mechanical Design

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Bridges are important structures, often playing a vital role in society, connecting communities, enabling easy access over complex terrains and providing aesthetic purpose. Bridges are therefore infrastructurally, socially and psychologically beneficial to society. As such, there is importance in considering structural aspects alongside architectural aesthetics when designing bridges. Structures in nature often have coupled benefits. Many structures are aesthetically pleasing to the human eye, whilst also serving structural and mechanical roles. In this paper, we explore beauty in the form and structure of diatoms. We take a bioinspired approach to bridge design by computationally imitating and integrating the complex geometrical pattern of diatom frustules into the bridge design. Diatoms are single-celled algae that are protected by bioglass frustules, each of which exhibits architectural symmetry and porosities. In parallel to designing the aesthetics of bridges, as inspired by diatom frustules, we concurrently parametrically design these architectures to improve the mechanical rigidity of the final bridge forms. Our abstraction from diatom to bridge follows similar principles to analogical KoMBi models, considering specifically geometrical pore features from diatom species alongside their spatial distances and size variations. These abstractions are thus low-level abstractions focusing on geometrical properties such that their geometrical requirements are understood alongside their aesthetic and lightweight biological functions, which are subsequently transferred to bridge design either directly or in convoluted forms. Our initial designs are developed using non-uniform rational B-spline (NURBS) surfaces (Rhino-3D), and selected bridge forms are then modelled using the finite element analysis (FEA) method to ascertain optimal hole sizes and positions (COMSOL Multiphysics) in relation to their fundamental mechanical properties such as tensile and compressive strength and stiffness. Our results yield innovative, artistic and efficient bridge architectures optimised for structural integrity and load bearing.

sciforum-086556: Future Advancements and Potential Applications of Biomimetic Sensors in Agriculture

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Global population growth, environmental degradation, climate change, and geopolitical issues are putting pressure on sectors like agriculture, forestry, water management, environmental protection, and biodiversity preservation, making the sustainable use of the environment a growing challenge. The potential uses of biomimetic sensors in agriculture and other sectors have drawn a lot of interest in recent years. Despite extensive research on biomimetic sensors in general, a comprehensive analysis of their unique applications and developments in agriculture is still lacking. Hence, this paper aims to provide a comprehensive understanding of the future advancement and application of biomimetic sensors' potential in various sectors, highlighting their potential in agriculture. Through synthesizing the available literature from the last 10 years, this paper delves into the integration of biomimetic sensors in agricultural practices, highlighting potential benefits and identifying current limitations, challenges, and construction. It will encourage researchers, experts, and industry professionals to explore new ways to enhance biomimetic sensor capabilities in the agricultural sector. This review suggests that biomimetic sensors in agriculture require further studies to develop advanced technologies, optimize design, enhance capabilities, and functionality, and integrate fields like biology, materials science, and engineering. Integrating data analytics and machine learning could lead to precision agriculture and real-time crop health monitoring.

sciforum-085080: Influence of Bionic Leading-edge Protuberances on the Horizontal Axis Wind Turbine

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The horizontal axis wind turbine is prone to flow separation during operation, which can affect the flow characteristics of the wind turbine and lead to performance degradation. As one of the methods of passive control, the leading-edge protuberances of the humpback whale have been proven to suppress flow separation and enhance performance. This study employs biomimetic principles to investigate the flow control mechanism by adding bionic leading-edge protuberances to wind turbine blades. The three parameters (amplitude, attenuation and number) that control the protuberances are nonlinear and non-uniform. The influence of leading-edge protuberances on the aerodynamic performance of a wind turbine is analyzed via the computational fluid dynamics method. The results indicate that the addition of protuberances can improve airfoil performance, increase the low-pressure area, and delay flow separation. For the single leading-edge protuberance, the pressure coefficient of the peak section decreases, and the pressure coefficient of the trough section on both sides increases. In this research, the bionic protuberance parametric structure applied to the blade leading-edge of the horizontal axis wind turbine proposed is a supplement to the existing bionic design method, which provides new research data for improving the design of wind turbine blades by using biomimetic principles. In addition, it holds practical value for guiding practical applications.

sciforum-089551: Mechanism of Motile Plants and Robots Inspired by Plants

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Plants are ideal for soft robot design due to their favourable ability to adapt and respond to the environment. Here, three different motile plants, bird of paradise (*Strelitzia reginae*), the waterwheel plant (*Aldrovanda vesiculosa*), and the Venus flytrap (*Dionaea muscipula*), are introduced. They may deform following the physics predetermined by the structure. As a decentralised species, plants respond under environmental stimulation without a controlling unit like a brain and motor-like muscles. The mechanism behind the movement of the plant should enlighten more intelligent robotics. In this study, movable plants are compared for their actuating principle, and, based on their deformation model, three pneumatic actuators are designed. The bird of paradise opens its petals when the sunbirds sit on another petal, which inspires the structure utilising the bending of the midrib to open lobes. Similarly, the waterwheel plant stores energy in the bending midrib and releases it when it closes. But, the Venus flytrap takes advantage of snapping to achieve rapid closure. Using three-dimensional (3D) printing, pneumatic actuators, which are ruled by the mechanism of plants with silicon rubber surfaces, are fabricated and tested. Under air pressure, the actuator deforms, mimicking the plant cells expanding under the turgor pressure. The hingeless actuator performs well while interacting with dedicated projects.

sciforum-086603: Numerical Investigations into the Cavitation Performance of a Bionic Hydrofoil with Discontinuous Leading-Edge Protuberances

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The humpback whale's unique and sensitive hunting ability in the ocean is due to the leading-edge protuberances of its flippers, which is also a viable passive control method for flow separation and cavitation. In this paper, the linear leading-edge of NACA 63_4-021 foil was modified, and a bionic hydrofoil with discontinuous sinusoidal leading-edge was constructed. The wavelength and amplitude were $\lambda = 0.25C$ and $A = 0.025C$, respectively, and the distance between adjacent protuberances was 0.25λ. The cavitation performances of the basic hydrofoil and the bionic hydrofoil with a cavitation number of 0.8 were numerically studied using the large eddy simulation method. The instantaneous flow characteristics of the hydrofoils were reported, including the lift and drag coefficients, pressure fluctuations, and the cavitation evolution. It was found that the flow of the discontinuous sinusoidal leading-edge hydrofoil showed obvious periodic patterns in the span direction, which changed the cavitation characteristics of the hydrofoil. The streamwise vortices induced by the protuberances restricted the incipient cavitation to the trough region and inhibited the cavitation near the peak section. Compared with the basic hydrofoil, the cavitation volume of the bionic hydrofoil was reduced by 35.94% at the 15° angle of attack, the stability of cavitation flow was stronger, and the standard deviation of pressure coefficient near the leading-edge of the suction surface was reduced by up to 50%. This study verified the feasibility of the discontinuous protuberance structure to inhibit the hydrofoil cavitation, which can provide theoretical guidance for the blade design of hydraulic machinery.

sciforum-086687: Numerical Simulation Study of Airfoil with Multiple Biomimetic Leading-Edge Protuberances

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Airfoils are widely used in fluid machinery, and airfoil stall is an important reason for equipment safety hazards. Biomimetic leading-edge protuberances are considered a potential means of stall control. In this study, the Transition SST turbulence model was employed to carry out a numerical simulation on the NACA 634-021 airfoil. The airfoil consists of a leading edge with 30 protuberances, forming an unusually wide wing. This configuration has never been previously investigated and is novel to this research. The results showed that the bio-inspired airfoil reduced the maximum lift coefficient by 14.2% and advanced the stall angle by 8°. The biomimetic airfoil exhibited excellent performance after stall. The maximum lift coefficient increased by 25.1% and the lift-to-drag ratio increased by 21.8%. At high angles of attack, due to the influence of the protuberance peak attachment flow, the suction surface flow field formed an alternating distribution of expansion and contraction. This validated the correctness of the conclusion that the suction surface flow field of the biomimetic airfoil exhibits periodic distribution at low angles of attack and non-periodic distribution at high angles of attack. Biomimetic airfoils have advantages in working with large changes in the angle of attack. This provides a theoretical basis for the application of biomimetic protuberances in vertical axis wind turbines and fixed-wing drones.

sciforum-086418: Optimized Design and Propulsion Performance of the Robotic Sea Lion Foreflipper

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Otariidae are the only marine mammals that use their foreflippers for propulsion, and the combination of hydrofoil and paddle propulsion makes them excellent hunters and swimmers. Therefore, it is of great scientific significance and engineering value to develop a novel underwater propulsion technology inspired by the propulsion mode of Otariidae foreflippers. At present, research on the Otariidae foreflipper-inspired propulsion is still in the initial stage and needs to be explored further in terms of both theory and technology. The bionic underwater robot team led by Prof. Liu of Tianjin University has made some achievements in this regard. Taking the California sea lion as a bionic prototype, they developed the first-generation biomimetic robotic sea lion foreflipper propulsion mechanism (Rob-flipper-I for short). In this study, the Rob-flipper-II is developed through the optimization of the Rob-flipper-I, which is composed of a driving mechanism and a pair of bionic foreflippers. The driving mechanism consists of a wobbling disk mechanism and a spatial linkage mechanism that are connected in series, and the bionic foreflippers have similar flexibility and mechanical properties to those of the sea lion foreflippers. The Rob-flipper-II can reproduce the spatial trajectory and attitude of the sea lion foreflippers by a single drive only. Based on the kinematics analysis of the Rob-flipper-II, the formulas for calculating the thrust and lift of the bionic foreflipper are derived, and the functional relationship between the motion speed of the bionic sea lion robot and the flapping frequency of the bionic foreflippers are obtained. In addition, the propulsive efficiency of the Rob-flipper-II is calculated. The tank experiment shows that the average thrust and propulsive efficiency of the Rob-flipper-II are higher than those of the Rob-flipper-I.

sciforum-089613: Parametric Algorithms Used as a Design Tool for Auxetic Structure Development

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This study delves into the realms of Parametric Design and Auxetic Structures, focusing on structures exhibiting unconventional behavior, i.e., those that have a mechanical function inverse to the conventional one and expand when subjected to an external force (giving them anti-rubber properties due to their negative Poisson's ratio). It explores the theoretical underpinnings, historical evolution, and diverse applications of these structures across architecture, engineering, biology, design, and art. Through the lens of three case studies, the study showcases the utilization of Rhinoceros and Grasshopper software used for designing grids based on auxetic structures, offering versatility in adapting to various shapes and dimensions. Furthermore, the authors introduce a parametric algorithm leveraging Rhinoceros and Grasshopper digital tools, facilitating the manipulation of tessellations' dimensions, quantity, and line thickness. This algorithm generates intricate three-dimensional models amenable to 3D printing technology. The research concludes with an insightful analysis of the potential applications of these technologies, emphasizing their inherent advantages and the challenges they pose for design and innovation across multiple domains of knowledge. By shedding light on the transformative capabilities of parametric design and auxetic structures, this work underscores their significance in fostering innovation and pushing the boundaries of traditional design paradigms.

sciforum-089157: Pneumatic Prehensile Gripper for Slender Objects with Embedded Fiber Reinforcement Structures

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Tendril-like structures curl around plant stalks and can be regarded as effective manipulators toward an object. The light structure has flexibility and resilience. In this project, the prehensile actuator is reinforced by fiber panels with inspiration from a tendril-like plant, and a convenient pneumatic soft gripper is fabricated for slender objects which are difficult to manipulate with normal grippers. The actuator is made of human-friendly silicone and utilizes compressed gas. The movement, stiffness, and load capacity should be improved in new designs. Therefore, inspiration is found from gelatinous fibers studied by botanists, and the cross-section structure of tendril-like plants provides a good example for soft actuators because fiber panels can be reinforced inside the actuators, with inspiration from tendril-like plant structures. In the new design, as shown in this research, a fiber-reinforced panel is inserted into the cross-section of the actuator. Meanwhile, it has little influence on the helix movement of the soft actuator. The mold is fabricated by a 3D printing method, and two-component silicone is used to make the physical model of the soft actuator. Variable materials of fibers are employed for the reinforcement panels, and experiments are carried out to obtain the important characteristics of the actuator, like movement ability and response time. With all this work, the actuator can be designed well and can form the basis for the further design of soft robots and potential manipulators. In this experiment, the actuator is tested as the gripper. Slender objects in ordinary life, like pencils, straws, and chopsticks, are manipulated by the prehensile actuating gripper, and the experimental results are analyzed and discussed.

sciforum-089619: Recent Advances in the Application of Smart Fibrous Scaffolds as Biomimetic Constructs for Wound Healing

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Regenerative medicine is a promising field that aims to reconstruct diseased or defective tissues. The primary goal of tissue engineering is to develop systems that can mimic the natural ECM using both natural and synthetic materials, and nanofibers are an excellent tool for this purpose. Electrospinning is a method for fabricating fibrous structures that offer great potential for the creation of biomimetic systems. Nanofibers mimic key aspects of the native ECM, making them a promising approach to improving tissue efficiency. Collagen and other extracellular matrix fibrous proteins with diameters in the nanometer or sub-micrometer range are abundant in the body, and porous nanofibers with high surface area and porosity can be used to mimic the ECM and promote tissue regeneration. Advanced bioactive dressings can be made using electrospinning. These dressings are popular due to their flexibility, ability to mimic the structure of the extracellular matrix (ECM), and ability to support the wound healing process. This emerging technology has the potential to create effective wound dressings and care products. There is a great focus on the development of suitable fibrous bioactive dressing materials for the treatment of chronic and acute wounds. Various composite fibers made from natural and synthetic polymers are used to create these dressings. Additionally, medicinal and biological agents are incorporated into the structure of fibrous dressings to control pain, prevent infection, and promote tissue repair and regeneration. This ensures that the wound-healing process progresses smoothly without any possible complications. As innovation progresses, more complex systems are developed in a controlled manner.

sciforum-086674: Research on the Shape of Biomimetic Airfoil Leading to Edge Protuberance

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Wind turbines and other fluid machinery can experience stalls during operation, leading to highly transient and heavy load fluctuations that jeopardize the structural integrity of the turbines and result in fatigue failure, significantly reducing performance. Inspired by the protuberance on the leading edge of a humpback whale's pectoral fin, eight different configurations of protuberances were added to the leading edge of a NACA 0021 airfoil segment with a span of 0.24 m as a passive control method to investigate their inhibitory effect on flow separation. The protuberance structures altered the pressure distribution on the airfoil's leading edge, particularly reducing the pressure at the trough after stall, allowing the fluid to reattach to the airfoil surface and delaying the onset of dynamic stall. The most significant improvement in alleviating airfoil stall was observed with the protuberance structure composed of a quarter-circle with a radius of 0.02 m and a quarter-circle with a radius of 0.01 m. At an angle of attack of 22° after the original airfoil stall, the lift coefficient increased by 6.7.7%. At the initial angle of attack of 4°, the lift coefficient increased by 60.4%, and then maintained a stable linear growth at various angles, with no stall occurring at the 24° angle of attack. This study provides inspiration for the design of bionic airfoil protuberance on structures and has guiding value for practical applications.

sciforum-086652: Shift In Architecture from Bioinspiration to Biomimicry: Trends and Perspectives

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Though historically this has not always been the case, science and art and architecture frequently go well together. Researchers who investigate the biological principles, structures, and functions of different natural things are engaged in the multidisciplinary area of biomimetics. Architecture contributes to the conversation within the profession, whereas art concentrates on producing visual objects for enjoyment. Bioinspired design is included into all facets of work at all scales through the combination of art, architecture, and biomimetics, or bio architecture. Utilizing biological principles to inform design is a creative process known as bioinspiration. In order to address real-world issues with innovation and sustainable development, the recently emerging multidisciplinary area of "biomimicry" combines scientific and technical aspects of biology with other disciplines. Both the social and natural sciences have an impact on architecture, and design activities often incorporate biological research. Through historical to contemporary bio architectural trends, bioinspiration has changed and moved architectural practices towards inventive ways. The distinction between replicating natural forms and comprehending biological principles is blurred by biomimicry in architecture, which is important for sustainable development. The main obstacle is the disparity between the creative process of architectural design and the deep understanding of biology and associated scientific domains; this calls for interdisciplinary collaboration. In this article, techniques are defined and applied to architectural design through case studies, examining bio architectural motions and their impact on biomimicry. Opportunities, difficulties, and the field's prospects for the future will all be discussed.

sciforum-089395: The Impact of Simple Layering and Layer Rotation Design on the Natural Vibration Performance of Grid Beetle Elytron Plates

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This study analyzes the natural vibration characteristics of grid beetle elytron plates (GBEPs), a type of laminated plate inspired by the sandwich structure of beetle forewings, under different angles of rotations.

Introduction

Inspired by the forewing structure of *Trypoxylus dichotomus*, GBEPs have been developed, exhibiting superior mechanical properties over traditional grid plates. This research investigates the effect of layer rotation on the natural vibrational frequencies of GBEPs, a crucial consideration for engineering applications.

Methods

The study utilizes COMSOL Multiphysics 6.1 and the ARPACK solver to analyze the vibrational response of GBEPs. Two identical plates were layered and rotated at angles from 0 to 45 degrees, in 9-degree increments, to examine changes in the first 9 natural frequency modes under various rotational configurations.

Results

Rotational adjustments significantly enhanced the clarity of vibrational modes, with dual-layered GBEPs showing more defined first 9 natural vibration modes compared to non-rotated structures. Rotation induced up to a 12.87% shift in natural frequencies, demonstrating the efficacy of this method in modulating vibrational characteristics.

Conclusion

This investigation highlights the capacity of simple structural modifications in biomimetic designs to achieve desired vibrational performances. Adjusting the orientation of layers in GBEPs allows for flexible vibrational properties, paving the way for their versatile application in different engineering contexts. The study leverages biomimetic principles to offer a novel approach for precise vibrational tuning in material design.

sciforum-086698: The Regenerative Potential of Biomimetic Construct Based on Hydrogel Loaded with Biological Agents and Hypoxic MSCs

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Introduction

Skin tissue engineering is a novel approach used to treat skin damage that has gained popularity in recent times. Hydrogel scaffolds are commonly used to promote wound healing. Studies have shown that chitosan, alginate, and ascorbic acid are highly effective in this regard [1, 2, 3, 4]. Ascorbic acid, used as a biological agent, plays a significant role in wound healing by increasing repair intermediaries and decreasing inflammation at the wound site [**?**]. Applying hypoxia has been shown to enhance the therapeutic performance of mesenchymal stem cells [**?**]. Moreover, hypoxia-inducible factor-1 (HIF-1) plays a crucial role in wound healing and remodeling [**?**]. The aim of our study is to investigate the role of biological agents and MSCs loaded onto biomimetic constructs based on chitosan—alginate hydrogel and determine their performance under hypoxic conditions.

Methods

Biomimetic constructs based on chitosan—alginate hydrogel were mixed with ascorbic acid and cross-linked with CaCl2. The scaffold's physicochemical properties, including swelling and biodegradation rates, wettability, and FTIR analysis, were assessed. Further analysis was conducted using MTT, DAPI, and H&E staining. The study investigated the expression of key genes (HIF-1α, VEGF-A, and TGF-β1) involved in the healing of skin wounds under hypoxic and normoxic conditions using real-time PCR.

Results and Conclusions

The study revealed that the biomimetic construct based on chitosan—alginate hydrogel was highly porous, biodegradable, and had a high swelling capacity. The hydrogel was not only hydrophilic but also compatible with blood. The hydrogel provided a suitable substrate for cell growth and proliferation, as indicated by MTT, DAPI, and H&E staining tests. Under hypoxic conditions, MSCs showed increased expression levels of VEGF and TGF-β1 genes according to RT-PCR analysis. Based on the results, a biomimetic construct made of chitosan—alginate hydrogel seeded with hypoxic MSCs could be a promising approach to improving wound healing.

Abstracts

Session 3. Biomimetic Surfaces and Interfaces

sciforum-084250: Can Biomimetic Superhydrophobic Surfaces Resist Underwater Biofouling?

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In exploring the biofouling resistance capabilities of biomimetic superhydrophobic surfaces, femtosecond laser technology was employed to create these surfaces, leading to comprehensive anti-fouling efficacy evaluations. Laboratory tests assessing surface contact angle, roughness, and chemical stability were conducted, alongside extended testing in simulated marine and freshwater environments. These tests aimed to determine whether these surfaces could maintain their anti-fouling properties under various environmental conditions. The results from controlled laboratory conditions indicated that these surfaces exhibited excellent hydrophobicity and chemical stability, suggesting potential effectiveness against biofouling. However, when subjected to more complex, real-world aquatic settings, the performance of these surfaces was not as effective as anticipated. Initially, the surfaces showed promise in resisting fouling, but over time, their effectiveness significantly diminished. This decline in performance was attributed to the accumulation of biofouling agents, such as proteins and polysaccharides, which facilitated the adhesion of various fouling organisms. This gradual buildup of biological material highlighted a critical limitation of superhydrophobic surfaces in dynamic aquatic environments. These findings challenge the previously held assumption that superhydrophobic properties alone are sufficient for effective biofouling resistance. It becomes evident that environmental factors play a significant role in the performance of these surfaces. This study underscores the need for future research to focus on the environmental impact on anti-fouling surfaces and to explore the integration of superhydrophobic features with other anti-fouling technologies. Such multidisciplinary approaches could lead to the development of more effective and durable solutions to combat biofouling, which is a persistent problem in marine and freshwater systems.

sciforum-086731: Penetration Mechanism of the Model Based on *Legionella gormanii* Bacterial Membranes Using the LL-37 Peptide

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Introduction

The LL-37 peptide, the only cathelicidin secreted in human organisms, can resist numerous pathogens as a part of an immune system. The efficiency of LL-37 antimicrobial action is dependent on the bacterial membrane composition, the percentage of phospholipid classes, their mutual proportions, and the types of fatty acid chains. The presence of choline in the growth environment for bacteria alternates the composition and physicochemical properties of their membranes, which then affects the LL-37 activity. In this study, the influence of the antimicrobial LL-37 peptide on the phospholipid monolayers at the liquid—air interface mimicking the membranes of *Legionella gormanii* bacteria was analyzed.

Methods

The Langmuir monolayer technique was used to prepare model membranes composed of individual classes of phospholipids (phosphatidylcholine (PC), phosphatidylethanolamine (PE), cardiolipin (CL), phosphatidylglycerol (PG), and their mixtures isolated) from *L. gormanii* bacteria supplemented or not with exogenous choline. In order to determine the peptide's mechanism of action, penetration tests were carried out for the phospholipid monolayers compressed to a surface pressure of 30 mN/m, and the peptide was then dispensed to the subphase. The changes in mean molecular area were observed over time.

Results

The results show the diversified effect of LL-37 on the phospholipid monolayers depending on the bacteria growth conditions. The choline presence in the medium affects the molecular profile of phospholipids in the bacterial membranes, determining the greater activity of the peptide. Our findings demonstrate that notable peptide insertion and disruption of the lateral packing and ordering can cause membrane destabilization.

Conclusions

Changes in membrane structure due to its interactions with LL-37 demonstrate a feasible mechanism of peptide action at a molecular level. Its determination is crucial for the design and development of antimicrobial peptides as an alternative to conventional antibiotics.

sciforum-086466: Biomimetic Approaches for Design of Antimicrobial Paper Barrier Coatings with Hierarchical Surface Structure

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The design of functional paper coatings with excellent barrier properties towards water and oxygen ingress in parallel with the enhanced recyclability of the coating layer is highly demanded, in view of sustainable applications for paper as a food packaging material in the industrial context. Therefore, enhanced functionalities of the coating layers should be incorporated through a combination of selected bio-based materials and the creation of appropriate surface textures that enhance coating performance. Bio-inspired approaches, through the replication of hierarchical surface structures with multi-scale dimensional features, in combination with the selection of appropriate bio-based functional groups offer new concepts for coating design. In this overview, some of the recent advances in the field are illustrated with a focus on the combination of hydrophobic and anti-microbial coating functionalities. Based on our long-term work with an available toolbox of bio-based building blocks and nanoscale architectures, they can be processed into applicable aqueous suspensions for paper coating deposition. The macroscopic roughness profile of paper substrates can be complemented through the decoration of nanoscale bio-based polymer particles of polyhydroxybutyrate from vegetable oil capsules with dimensions in the range of 20 to 50 nm or 100 to 500 nm, depending on the synthesis conditions. The anti-microbial properties can be provided through the surface modification of nanocellulose with biologically active molecules sourced from nature. Aside from the more fundamental issues in design and synthesis, the industrial application of bio-inspired coatings under spray-coating application becomes relevant.

sciforum-086636: Butterfly Wing Scales as Inspiration for Multifunctional Building Surfaces

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Global warming advances and urban areas are plagued by increasingly intense heat waves every summer, pressing a dire need to cool down cities.

Butterflies can inspire us in this matter, as they benefit from various multifunctional nanostructures on their wing scales. The properties range from structural coloring, hydrophobicity and self-cleaning properties to structural integrity and passive thermoregulation. Recent research on scent scales—special scales, used by butterflies to distribute pheromones—indicates that they exhibit interesting thermal properties, especially within the atmospheric window (the wavelength spectrum from 7.5 μm–13 μm, where our atmosphere is transparent for radiation within that range).

This work aims to investigate different kinds of butterfly scales on a micrometer and nanometer scale for potential application in the thermoregulation of buildings.

With Scanning electron microscopy (SEM) and Focused ion beam (FIB) techniques it is managed to cut into single scales, to analyze the cross-section of these structures and to provide first expert guesses about structure-function relationships. Color scales, scent scales and reflective scales from various butterfly species (both tropical and native to the temperate zone of Middle Europe) are compared, to determine, whether specific nanostructures could be responsible for thermal features such as passive radiative cooling.

sciforum-086722: Development and Characterization of Hydroxyapatite Coatings with a Biomimetic Plate-like Morphology

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Introduction

Modern medicine depends on biomaterials. Thus, it is imperative that these materials continue to be developed and improved.

Methods

This work aimed at designing hydroxyapatite-based coatings (HAp) with high osseointegration properties by developing a biomimetic morphology that resembles that of natural HAp found in bone tissue. The biomimetic HAp coatings with plate-like morphology were successfully obtained using the pulsed galvanostatic electrochemical approach on pure Ti discs. The coatings were investigated in terms of surface morphology, chemical and phasic composition, in vitro bioactivity, and cell interaction.

Results and Discussion

The morphological investigations revealed that using electrochemical deposition, HAp-based coatings with very thin and wide plate-like crystals can be obtained. The chemical composition highlighted that both Ca and P are present, and that the Ca/P ratio registered values of 1.66, being close to that of the stoichiometric HAp of 1.67. The phasic composition analysis showed that the main phase consisted of hydroxyapatite (ICDD #09-0432), with a crystallinity of ~25%. The biomineralization ability of the cp-Ti substrate was improved by the HAp-based coatings, reaching a maximum value of 9.7 mg after 3 weeks of immersion in simulated body fluid (SBF) compared to the Ti samples which gained a mass of only 0.3 mg after the same period. The in vitro experiments using human mesenchymal stem cells demonstrated that the HAp-based coatings enhanced the extracellular matrix, the intracellular deposition of Ca, and cell viability when compared to the cp-Ti substrate, demonstrating the advantages of the developed coatings.

Conclusions

Therefore, the outcomes confirm that coatings with improved and adjustable properties can be designed for medical applications by using the electrochemical deposition technique.

Acknowledgments

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sciforum-089531: Electrochemical Additive Manufacturing of Cicada-Inspired Fluoridated Hydroxyapatite Nanostructured Surfaces

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We use electrochemical additive manufacturing method to combine cicada-inspired nanostructures and fluoridated hydroxyapatite (FHA) solutions, and give full play to their physical and chemical antibacterial advantages. We prepared cicada-inspired fluoridated hydroxyapatite nanostructured surfaces on the surface of acid etched titanium for the first time. It consists of closely aligned single FHA nanopillars. The diameter of a single FHA nanopillar is about 65–95 nm, the height is about 380–510 nm, and the aspect ratio is about 4.5–7. It has high crystallinity, long-range regularity and defect free lattice with the [0001] (i.e., [001], c-axis) crystallographic orientation. It is expected to be applied to orthopedic and dental implant surgery in the future.

Introduction

With the rapid development of modern medicine, implant surgery has gradually become more important. However, due to the use of antibiotics, the bacterial infection of implantation becomes difficult to overcome. Therefore, we urgently need to find non-antibiotic antibacterial methods. Recently, cicada-inspired nanostructures and fluoridated hydroxyapatite (FHA) solutions have attracted great interest for their remarkable bactericidal ability. But cicada-inspired nanostructures are not resistant to Gram-positive bacteria. In this study, we aimed to develop fabricating nano-structures with bioactive and biocompatible properties.

Results & Discussion

The cicada-inspired FHA nanostructure deposition layer was successfully formed on an AETi plate of which size is $9 \times 9 \times 1$ mm. It consists of closely aligned single FHA nanopillars. The diameter of a single FHA nanopillar is about 65–95 nm, the height is about 380–510 nm, and the aspect ratio is about 4.5–7. The fluorine concentration (2.22 at.%) and Ca/P ratio (1.61) are similar to those of the $Ca_{10}(PO_4)_6(OH)F$ (fluorine concentration = 2.33 at.%, Ca/P = 1.67).

Conclusions

This study provide a novel, economical and time-saving method to prepare cicada-inspired nanostructured surfaces, which may enhance the antibacterial activity of orthopedic and dental implants and lay the foundation for better biological applications in the future.

sciforum-089677: From Fish Scales to Dynamic Ice Removal Mechanisms

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The effects of static surface properties, such as free energy, toughness, elasticity, etc., on icephobicity have been extensively studied and documented. However, the role of dynamic surface characteristics in ice detachment remains unclear. This study examines the ice adhesion strength of authentic Arctic salmon (Salmon salar) skin by shear test. The results indicate a 60% reduction in ice adhesion strength when sheared against the growth orientation of fish scales compared to shearing along this orientation, revealing an intriguing anisotropic ice adhesion behavior of the fish scales. With the aid of molecular dynamic simulation, a distinctive structural evolution of fish scales, opening and peeling during ice shearing against the growth orientation, is revealed, resulting in a sequential rupture process and thereby significantly lowering the adhesion compared with concurrent rupture. The opening and peeling capacity of fish scales can be defined as the ability of individual scales to separate from their underlying structures and adhesives under applied force. Enhancing this capacity can further reduce ice adhesion strength, facilitating effortless ice detachment on fish scales. The mechanical robustness of fish scales offers new possibilities for designing hard and durable anti-icing surfaces. This opens a new avenue for understanding and designing surfaces with tailored adhesion mechanics.

sciforum-089589: How Nanopores and Microcavities Control the Light Reflectance Properties of Snake Ventral Scales

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All natural organisms have adapted themselves for survival over millions of years of evolution. For example, snakes have developed nanofeatures on their ventral scales in specific geometry and orientation to ease their locomotion. In addition to that, some snakes have also optimized their scales to control their thermoregulatory and optical properties. Some snakes living in hot and humid equatorial climates have developed reflective white ventral scales to avoid overheating caused by highly radiative soil and rocks. Our analysis shows that nanopores embedded inside these ventral scales scatter light to achieve reflective white surfaces. Interestingly, they are also highly reflective in the near-infrared regime of the electromagnetic spectrum, which might help them to avoid overheating. In comparison with these reflective scales, amorphous structures, rather than nanopores, have been found in transparent/translucent scales. These transparent/translucent scales showed greatly reduced reflective qualities in visible and near-infrared light. Some snakes have developed silvery-white ventral scales. Instead of nanopores, alternating layers of microcavities are found in the scales of these species. Our experimental results suggest that these layers interact with visible light to develop silvery-white surfaces utilizing a “chirped mirror” mechanism. In my presentation, I will discuss several examples of how snakes optimize their optical properties.

sciforum-086638: Infrared Management in Nature and Bioinspired Applications

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The regulation of body temperature and the mastery of thermal radiation control stand as fundamental survival mechanisms for diverse animal species. Evolution over millions of years has fine-tuned natural systems, particularly in cold-blooded organisms like insects, as well as those facing extreme temperature conditions, such as polar bears, Arctic foxes, and dromedaries. These creatures have developed unique integumentary features to optimize thermal radiation absorption and regulation [1].

This conference contribution delves into selected natural case studies, focusing on the intricate designs found in butterfly wings and animal furs. These natural structures, honed by evolution, serve as a wellspring of inspiration for developing innovative materials with enhanced energy efficiency for infrared absorption and thermal insulation. By examining the biological adaptations that enable these organisms to excel in thermal regulation, we can draw insights to inform the design, development, and fabrication of materials that mimic these features [2].

Through the exploration of bioinspired applications, this presentation will underscore the potential for translating biological principles into practical solutions. By bridging the realms of biology and materials science, attendees will gain a deeper understanding of how nature's innovations can guide the creation of advanced structures capable of efficient thermal management. This interdisciplinary approach holds promise for applications in diverse fields contributing to the development of sustainable and energy-efficient solutions.

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sciforum-086569: Physicochemical Characterization of TiO_2/Polysaccharide Systems in Terms of Biocompatibility

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The aim of the presented research was the physicochemical characterization of a biomaterial based on chitosan, hyaluronic acid and titanium dioxide(IV) in relation to biocompatibility and antibacterial characteristics for application in the cosmetic, medical and pharmaceutical industries. Chitosan and hyaluronic acid were chosen due to their potential application (e.g., artificial skin and wound dressings), and titanium oxide(IV) was chosen to increase mechanical stability. The parameters with crucial effects on stability and biological environment response, and also those responsible for the antibacterial properties of the biomaterials, were described. The physicochemical properties of two- and three-component dispersions based on chitosan, hyaluronic acid and/or titanium oxide(IV) of different mass ratios were described in relation to energetic and topographic parameters. Knowledge of such parameters is necessary to predict and control the behavior of cells, which determines the proper functioning of the biomaterial in the living organism, indirectly providing information about biocompatibility.

The experimental data provided using the Langmuir technique, coupled with the Brewster angle microscope, gave insight into the interactions existing between the individual dispersion constituents and phospholipid molecules forming the model biological membranes. In order to characterize the biomaterial/cell membrane interactions precisely, two kinds of phospholipids which differ in their structure, 1,2-dipalmitoilo-*sn*-glycero-3-phosphocholine (DPPC) and 1,2-dioleoilo-*sn*-glycero-3- phosphocholine (DOPC), were used. Moreover, the 1,2-dipalmitoilo-*sn*-glycero-3-phospho-rac-(1-glycerol) sodium salt, being the typical component of bacterial *Escherichia coli* and *Staphylococcus aureus* membrane, as well as lipids extracted from these bacteria were used. The bactericidal capacity of the tested system was interpreted based on the colony forming the unit (CFU)-counting assay and LIVE/DEAD staining shared with the fluorescence intensity measurements. The obtained results significantly contribute to a broader understanding of the interactions of components of different polarities, with biological membranes confirming the need for a multifaceted view using biomimetic methods.

sciforum-084928: Tailoring Wettability Control of Superhydrophobic Metallic Surface via Sustainable Fabrication Approach

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Introduction

Wetting affects chemical and physical properties. In aluminum, superhydrophobic surfaces keep fog, ice, and corrosion at bay. Biomimicry replicates natural processes. The high surface energy of aluminum limits its intrinsic dewetting properties. Existing surface modification methods have disadvantages, such as hazardous chemicals, high costs, and harsh processing conditions. This work is environmentally friendly and overcomes traditional limitations.

Methods

Aluminum alloy plates (AA5083) of commercial grade (ASTM-B-209M) were used in the study. Stationary friction stir processing (sFSP) was carried out on a universal milling machine focused solely on surface characteristics using transition metal powders (99% purity). The prepared samples were polished with abrasive papers to 1000 grit after processing. In the microwave hot water treatment (mHWT), processed and unprocessed samples were processed for 10 min at 800 W. A silanization agent was vapor-deposited on the samples following mHWT at 55 °C for 60 min.

Results

The low-strain-rate sFSP of aluminum alloys results in substantial grain refinement, reaching ~1 μm for processed samples and ~ 30 μm for unprocessed samples. Refined grains have a dense and networked nanostructure after mHWT. After silanization, the samples exhibit excellent contact angles (>155°), low tilt angles (10°), and low contact angle hysteresis (5°). The processed samples, featuring highly refined grains, demonstrate low water adhesion (~16 μN) compared to unprocessed samples (~50 μN), attributed to the high interfacial energy of the Cassie state, effectively entrapping air. These processed samples exhibit remarkable de-wetting properties and mechanical resilience, owing to the strong negative capillary pressure (>1100 kPa) generated by highly dense networked nanostructures.

Conclusions

In conclusion, the research helps to develop sustainable and durable superhydrophobic aluminum surfaces. The environmentally friendly and cost-effective strategies explored have far-reaching implications for industrial applications, emphasizing opportunities for advancements and practical utilization across various industries.

sciforum-086505: The Growth of Mycelium Covering with Sufficient Oxygen Permeation of PVC Plastic Food Wrap

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Mycelium-based composite (MBC) consists of the filamentous fungi of mushrooms, mycelium, forming a network with biodegradable agro-waste particles. MBC can be shaped in plastic molds; however, a higher density of mycelium was observed at the MBC surface exposed to the air (MBC/Air) than the MBC contact with plastic mold (MBC/Mold). Consequently, MBC was demolded to obtain uniform growth of mycelium on the substrate. This study investigated the effect of the oxygen transmission rate (OTR) of two different thin film materials, PVC plastic food wrap and stencil paper, on the growth of the mycelium of oyster mushrooms on sawdust. Each thin film was covered between the MBC and polypropylene (PP) mold in configurations of MBC/Film/PP Mold. The OTR of thin films was measured according to ASTM D3985. The results were compared with the OTR of a rigid PVC tube, PET-G, and PP cast, which were used as molds for shaping the MBC in previous literature. It was found that the mycelium was of a higher density in MBC/PVC film/PP and MBC/stencil paper/PP than the top surface of MBC/Air. The OTRs of stencil paper and PVC film were 11,777.78 cc-mm/m^2/day and 143.88 cc-mm/m^2/day, respectively, which were higher than those of the rigid PVC tube (3 cc-mm/m^2/day), PET-G (9.7 cc-mm/m^2/day), and PP cast (76 cc-mm/m^2/day). Despite the higher OTR found in stencil paper than in PVC film, the mycelium at MBC/PVC film/PP was denser than MBC/stencil paper/PP. This suggested that sufficient oxygen transmission through film contact with the MBC surface was necessary for the mycelium to grow homogeneously. Shaping the complex geometry of MBC can be possible without using the rigid plastic mold, yet only PVC plastic wrap is acceptable. The mechanical properties of MBC will be further investigated.

Abstracts

Session 4. Design and Control of Bioinspired Robotics

sciforum-086348: *Pilobolus*- and *Viola*-Inspired Precision-Based Seed Dispersal Device for Efficient Forest Restoration

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Introduction

Afforestation and reforestation (A/R) serves as the crucial cornerstone for the achievement of SDGs, effectively reversing climate change and curbing desertification. Drone-supported seed sowing (UAVsSS) represents a paradigm shift in rapid forest restoration, surpassing conventional methods [1]. However, the exploration of more advanced alternatives is necessitated by certain limitations, including a low seed survival rate (0–20%), sensitivity to high wind and precipitation, concerns about seed-firing accuracy, and adherence to country-specific aviation rules [2]. Biomimetics, drawing inspiration from nature's time-tested design for resilience, stands as the contemporary answer for complex design problems. The objective of this study is to design an inventive solution for accomplishing forest landscape restoration, guided by the principles of biomimetics.

Materials and Methods

Deriving inspiration from the phototrophic spore dispersal of the *Pilobolus* fungi, ballistic seed dispersal in Sweet Violet (*Viola odorata*) pods, and the adaptability of spiders in forest ecosystems, a sensor-based seed dispersal device has been designed. It is equipped with a GPS locator, light sensor, obstacle, and water surface detector. The device contains two seed chambers with native tree seeds of heliophytes and sciophytes. By constantly detecting sunlight penetration while moving on the ground, it disperses heliophyte seeds where sunlight penetrates more, and sciophyte seeds in relatively shaded zones. With spider-like maneuverability, it can navigate forest clearings, overcome obstacles like fallen trees, and even swim through water surfaces. Testing is conducted to assess its effectiveness in a simulated environment.

Results

Simulation demonstrates the device's adeptness in responding to varying light penetration and circumventing obstacles. The device accomplishes targeted seed dispersal based on detected light penetration by mimicking the natural dispersal behavior of *Pilobolus* fungi and *Viola odorata* effectively.

Conclusions

The results indicate that this device presents a viable alternative for UAVsSS, providing an efficient solution for precision-based rapid afforestation.

sciforum-086195: Enhancing Grasping Abilities through a Novel and Affordable Hybrid Exoskeleton Glove for Hand Rehabilitation

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Over the past few years, interest in wearable exoskeleton gloves has grown. These tools can be used to help those who are healthy or to support those who have neurological and musculoskeletal conditions like stroke, spinal cord injury, etc. The hand, which is the human body's most flexible limb, encounters more difficult problems and recovers considerably more slowly than the lower and upper limbs. In light of these difficulties, a novel therapy called exoskeleton-based rehabilitation has gained increased significance. In this work, we concentrate on creating a wearable exoskeleton glove that is inexpensive to improve the user's grasping abilities. The tool significantly raises the user's gripping capacity, which raises their quality of life. The exoskeleton glove is designed to assist human hands with limited mobility during the motion rehabilitation process and to improve the grasping and dexterous manipulation capabilities of the hands of both impaired and able-bodied individuals. The proposed model consists of two types of systems, mainly the tendon driven system and the pneumatic system. The tendon-driven system is the system that helps in the flexion and extension movements of the hand. The efficiency of the exoskeleton glove is evaluated by performing the basic movements of hand like abduction, adduction, flexion, and extension. The developed hybrid exoskeleton glove can efficiently enhance the grasping capabilities of its users, offering, affordable, lightweight and easy-to-operate solutions that can assist in the execution of activities of daily living (ADL).

sciforum-088888: Multi-FMAV Time-Varying Formation Control Method with Mixed Delay

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In the past decade, researchers have analyzed the flight mechanism of flying organisms, carried out in-depth attitude control, position control design, and the system stability analysis of FMAVs, and proposed several state estimation models and control methods to realize the autonomous formation flight of flapping-wing flying robots. Among them, in the distributed information interaction network environment, which comprises multiple FMAVs, the internal system and communication process are inevitably influenced by factors such as network topology, sampling methods, and flight conditions. Consequently, this interaction may lead to information incompleteness phenomena, including time-varying delays, random packet losses, and signal attacks. These phenomena, in turn, degrade the estimation performance of the desired state during FMAV cruise accompaniment, standoff tracking, and encircling flight, ultimately affecting overall formation effectiveness. To address these issues, this study introduces a novel multi-FMAV time-varying formation control approach, considering the presence of multiple time delays in dynamic feedback control. By employing appropriate system transformations using free power matrices, combined with an augmented multiproduct Lyapunov–Krasovskii functional that captures more time delay information and an improved Wirtinger and relaxed integral inequality method, the resolution error is reduced. This approach leads to stability conclusions with reduced conservatism and design conditions for the distributed H∞ state estimator. These advancements expand the stable operation domain of the system and provide a more intuitive understanding of the formation's convergence ability. The validity of these conclusions is demonstrated through simulation examples, providing insights into the future research directions of FMAV flight control.

sciforum-086660: Autonomous Aquatic Sentinels: Advancing Water Quality Assessment with Non-Intrusive Biomimetics Approach

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Introduction

The ongoing urbanisation and industrialization in developing nations produce hazardous wastes, including heavy metals such as iron, nickel, cobalt, cadmium, etc., and bring naturally occurring radioactive materials to the surface through anthropogenic activities. Apart from radionuclides in the uranium and thorium series, surface water may contain natural radionuclides like 40K, 3H, and 14C, with anthropogenic sources contributing to 90Sr, 131I, transuranium products, and other emitters [**?**]. Their gradual buildup in the aquatic environment poses a persistent threat of metal-related diseases and endangers both aquatic biota and other organisms [**?**]. The integration of biomimicry principles can be a transformative avenue for environmental monitoring and aquatic research. This study aims to design a biomimetic swimming fish bot with advanced detectors to revolutionise water sample collection, reduce human interaction, and address environmental health by swiftly managing potential threats from heavy metals and radioactive materials.

Materials and Methods

Drawing inspiration from the swift swimming motion of Sailfish (*Istiophorus platypterus*), the bot employs a specialised fin-like structure that mimics the hydrodynamic efficiency of marine organisms, allowing it to cover large areas efficiently. The bot's capability to assess heavy metal contaminants is influenced by the bioaccumulating prowess of Zebra mussels (*Dreissena polymorpha*). The device utilises a radiation detection module inspired by the colour-changing behaviour of Spiderwort (*Tradescantia virginiana*) flowers. Responding dynamically to radiation fluctuations, the sensors change colour for rapid and easily visible radioactivity analysis. Additionally, the entire device is powered by an energy-efficient system inspired by the metabolic efficiency observed in marine organisms. Testing is performed to evaluate its efficiency in a simulated environment.

Results

The simulation demonstrates the bot's efficiency in assessing water quality, showcasing excellence in propulsion, precise metal detection, and prompt responsiveness in radiation analysis.

Conclusion

The result validates this design as a state-of-the-art biomimetic robotic device for water quality assessment.

sciforum-086719: Bio-Inspired Neural Network for Real-time Evasion of Multi-robot Systems in Dynamic Environments

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In complex and dynamic environments, traditional pursuit–evasion studies may face challenges in offering effective solutions. This paper aims to provide a novel approach that approximates a general pursuit–evasion game from a neurodynamics perspective instead of formulating the problem as a traditional differential game. In this paper, the neurodynamics-based approach aims to overcome the limitations of the traditional approach and improve the performance of the evaders in dynamic and uncertain environments. A bio-inspired neural network is proposed that approximates a general pursuit–evasion game from a neurodynamic perspective. The bio-inspired neural network is topologically organized to represent the environment with only local connections, and the dynamics of neural activity are characterized by a neurodynamic model. The pursuer has global effects on the whole neural network, while the obstacles only have local effects to guarantee the robot avoids collisions. The real-time collision-free evasion trajectories are generated through dynamic neural activities. Simulation results indicate that the proposed approach is able to guide evader robots to evade the pursuer in complex environments with static, moving, and sudden-change obstacles. In addition, the comparison studies illustrate that the proposed approach is effective and efficient in complex and dynamic environments. This paper brings new insights into the application of the bio-inspired neural network in the field of robotics and also presents many potential practical application scenarios.

sciforum-089567: Caninoid Necro-Robots: Geometrically Selected Rearticulation of the Canine Mandible

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In line with Sustainable Development Goal 9 (sustainable industrialisation and innovation), environmentally responsible engineering designs in modern robotics should consider factors such as renewability, sustainability, and biodegradability. The robotics sector is growing at an exponential rate, and as a consequence, its contribution to e-waste is a growing concern. Our work contributes to the technology development of caninoid necro-robots, robots that are built from the skeletons of deceased dogs. The already formed skeletal structures of deceased dogs (and other animals) are ideal natural material replacements for synthetic robotic architectures such as plastics, metals, and composites. Since dog skeletons are disarticulated, simple but effective methods need to be developed to rearticulate their bodies. The canine skull is essentially a large end effector, but its mandible is held together by a fibrocartilaginous joint (symphysis) that degrades at a higher rate than the bone itself. The degradation of the symphysis would ordinarily negate the utility of a canine skull as a necro-robotic end effector; however, in this research, we consider simple methods of mandible reinforcement to circumvent this problem. Our research uses 3D scans of a real canine skull, which is modelled using the finite element method to ascertain optimal geometrical reinforcements for the mandible. The full skull structures and their reinforcements are printed and adhesively connected to determine the most effective reinforcing strategy for the mandible. Here, we elucidate geometrically selected reinforcement designs that are evidenced through mechanical testing, to successfully increase the stiffness of a disarticulated mandible.

sciforum-086757: CGull: A Non-Flapping Seagull-Inspired Composite Morphing Drone

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Introduction

Many avian species are well equipped for dynamic flight with flexible morphing wings and tails that optimize aerodynamic performance across various environmental conditions. As a result, imitating the shape-changing anatomical characteristics of birds can result in unmanned aerial vehicle (UAV) designs that outperform conventional fixed-wing UAVs in terms of flight performance. This rationale is the guiding principle behind the research on morphing aerospace structures.

Methods

This work presents CGull, a bio-inspired, non-flapping UAV with wing- and tail-morphing capabilities. CGull's target weight and size are based on the characteristics of the Great Black-Backed Gull (GBBG). A mathematical model was first developed in MachUpX to guide the selection of the design parameters for optimal performance at various morphing configurations. Only one morphing degree of freedom (DOF) was used in CGull's wing, which bends the inner wing forward and the feathered outer wing backward, replicating the seagull's wing deformation. A compact design of an actuation mechanism was proposed to control three DOFs in the tail: pitching, tilting, and feather expansion. Laminated composite structures were utilized in various components, such as the outer shell of the central body and the feathers. Computational fluid dynamics (CFD) and finite element analysis (FEA) simulations were performed to validate the design choices.

Results

A proof-of-concept prototype was built, and various tests were performed to prove the effectiveness of the proposed design.

Conclusions

The proposed bio-inspired morphing UAV design can replicate the GBBG's non-flapping flight effectively. The selected composite materials and servomotors enabled us to achieve the design objectives.

sciforum-086745: On The flight Control of Flapping Wing Micro Air Vehicles with Model-Based Reinforcement Learning

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Hummingbirds and insects can hover in disturbed conditions, escape from predators with a very fast response, fly for miles without landing, etc. These outstanding features are still unmatched by the most recent bio-inspired drones, due to complex aerodynamic phenomena that are underexploited by flapping wings. We propose an innovative control framework that blends model-free and model-based strategies to control the wing kinematics of Flapping Wing Micro Air Vehicles (FWMAVs) in a "take-off and hover" scenario.

The control strategy reunites a Reinforcement Learning approach (Deep Deterministic Policy Gradient), that mimics the trial-and-error learning process of natural species and an adjoint-based approach that interacts with a calibrated model of the environment. The approaches collaborate and learn from each other to be robust to highly dynamic maneuvers and sample-efficient. The approach is tested on a canonical drone formed of a spherical body and two semi-elliptical, rigid wings that operate within the hummingbird's range. The drone flight is simulated combining the equations of motion with a data-driven, quasi-steady model that estimates the wing aerodynamic forces. The controller adapts those forces by varying the wing motion, parametrized by three degrees of freedom, to reach the flight objective and satisfy an energy-minimization constraint.

The results show that the drone efficiently reaches its target thanks to the complex adaptation of its wing kinematics. The physics of the flight was also analyzed thanks to a high-fidelity CFD environment. This contribution thus shows a first proof of concept of a control algorithm that aims to bridge the gap between natural flyers and bio-inspired drone flight maneuvers.

Abstracts

Session 5. Poster Session

sciforum-086733: Thermodynamic Analysis of Interactions in Langmuir Monolayers Imitating Bacterial Membranes

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Introduction

Bacteria belonging to the *Legionella gormanii* species cause respiratory diseases. The key factor in the proper functioning and virulence of these microorganisms is the structure of biological membranes, the main components of which are phospholipids (PL). Their composition in the outer membrane layer of *L. gormanii* cells can change under various environmental factors, such as the presence of choline in the growth medium. Phospholipid distribution, the quantitative proportions of individual classes and intermolecular interactions define the physicochemical properties of bacterial membranes. The aim of the present research was the thermodynamic analysis of interactions occurring in model *L. gormanii* membranes with different phospholipid compositions.

Methods

Model membranes were created by means of the Langmuir monolayer technique using phospholipids isolated from bacteria grown with (PL + choline) and without (PL-choline) the addition of choline. To characterize the interactions between PL molecules in mixed monolayers, model single-component membranes of representatives of specific phospholipids classes were analyzed. The dependencies of surface pressure on mean molecular area (π-A isotherms) were obtained. Based on experimental data, the excess area A_{exc} and excess Gibbs energy of mixing ΔG_{exc} were determined.

Results

The PL-choline membrane, due to its higher content of anionic phospholipids, is characterized by stronger repulsive interactions, while the PL + choline membrane, containing mostly zwitterionic compounds, shows stronger attractive interactions in comparison to single-component monolayers. The increase in repulsive interactions between PL-choline molecules results in greater flexibility of the membrane and limited miscibility of the components. On the contrary, the increase in attractive forces in PL + choline causes the formation of more homogeneous and tightly packed membranes.

Conclusions

The determination of interactions occurring in bacterial membranes and their changes induced by external factors can contribute to the development of new methods of treating infections caused by *L. gormanii*.

sciforum-086150: Analyzing the Tribological Combination of Microstructure and Lubricant in Beetle Joints for the Development of Environmentally Friendly Lubricants

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Insects optimize friction in their joints by combining microstructures with a—so far unknown—lubricant. To develop environmentally friendly lubricants, we research the sophisticated tribological system found in the joints of beetles. We characterize the lubricant as well as the microstructure of the joints to gain inspiration for the development of a degradable and—hopefully—superior alternative to mineral-oil-based lubricants. However, restrained by the tiny quantities of beetle lubricant and the compactness of their joints, this tribological analysis is challenging. Therefore, we apply atomic force microscopy (AFM) to record the joints' microstructures and the lubricant's frictional properties. Furthermore, we research the inner structure of the bearing surface in beetle joints by focused ion beam (FIB) tomography. With this approach, we discover a network of channels supplying the lubricant to pores which represent the inlets of the hinged joint system. As a subsequent step, we analyze different types of presently available plant mucilage using AFM friction measurements to compare the suitability of plant mucilage as an alternative lubricant to the tiny quantities of beetle lubricant. Finally, we develop an artificial surface mimicking the microstructure of beetle joints. We determine its frictional properties utilizing colloidal AFM probes in the dry state as well as the lubricated state with plant mucilage as the lubricant.

sciforum-086467: Biocompatible Pillar[5]arene-Based Ionic Liquids Containing Amino Acid Fragments as Potential Water Treatment Systems

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Ionic liquids (ILs) are a rapidly growing area of technology and materials science due to their unique properties such as adsorption, recyclability, polarity, and thermal and electrochemical stability. Pillar[**?**]arenes are a new class of molecular receptors that have proven to be effective drug delivery systems by forming "host-guest" complexes and agents for the selective recognition of biopolymers. The development of ILs based on a non-toxic biomimetic macrocyclic pillar[**?**]arene platform will lead to a new generation of materials with programmable properties. The purpose of this work is the synthesis of new ILs based on decasubstituted pillar[**?**]arenes with amino acid fragments (glycine, glycylglycine, *L*-alanine, and *L*-phenylalanine) and the study of their thermal stability and the effect of substituents and counterions, as well as the absorption of water-soluble pollutants. Melting point determination and simultaneous thermogravimetry (TG) and differential scanning calorimetry (DSC) were used to study the thermodynamic properties of the ILs. UV spectroscopy was applied to study the interaction and absorption of contaminants by ILs.

Replacement of the bromide anion in the pillar[**?**]arene structure with NTf_2^- resulted in a more significant decrease in melting point (56–88 °C) compared to the PF_6^- anion (86–95 °C), which is logically related to the symmetry and density of the molecular packing. The onset of decomposition of the synthesized compounds was established at 240–300 °C. ILs with *L*-phenylalanine residues showed lower thermal stability and higher melting points compared to smaller fragments (glycine, alanine). The absorption of water-soluble contaminants by ionic liquids was shown to be possible, as expressed by a decrease in optical density.

The obtained results can be applied to the design of novel biomimetic supramolecular materials for substrate recognition and water treatment.

The work was supported by the Russian Science Foundation (№ 23-73-01087), https://rscf.ru/en/project/23-73-01087/.

sciforum-087820: Bioinspire-Explore: Browsing Biodiversity Data for Bioinspiration

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Bioinspiration's success requires straightforward access to biological data in a form that non-biologists can understand. In this poster, we present a new tool, "Bioinspire-Explore", which allows biomimicry practitioners to delve into global biodiversity data via a user-friendly interface (Saint-Sardos *et al*., 2024). Through this exploration, stakeholders can uncover biological models potentially relevant to a range of bioinspired fields and sectors. Bioinspire-Explore's entry point is a taxon of interest (i.e., species, genus, family, etc.) connecting the user to information regarding its position in the phylogenetic "tree of life", its distribution and climatic niche, as well as its appearance. This is achieved through linking Bioinspire-Explore to international databases, namely the Global Biodiversity Information Facility GBIF (based on the Catalogue of Life taxonomic backbone), WordClim, Wikidata, and INaturalist. Aside from presenting this fundamental biological and ecological information through a single interface, Bioinspire-Explore also allows users to assess the semantic proximity of relevant entities within a corpus of scientific literature pertaining to bioinspiration/biomimicry. This supports bioinspired design by offering potential connections between a taxon and its associated biological functions, environment, or physical characteristics. Bioinspire-Explore thus provides a unique way to explore biodiversity data and visualise biological relationships. This innovative tool acts as a guide, not a replacement for the active involvement of biologists in bioinspiration projects. Rather, it orientates the user towards promising information regarding living systems of interest and presents those systems in their scientific context. It is intended to create opportunities for education, insight, and interaction within bioinspiration teams interested in a "biology-push" approach to innovation.

sciforum-086628: Biomimetic Application of *Ianthella basta* Demosponge Capillary Structured Chitin Scaffolds

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Introduction

Macroporous chitinous scaffolds, derived from marine demosponges like Ianthella basta, have garnered significant interest in interdisciplinary research, particularly within the biomedical scientific community. This is primarily due to evolutionarily distinctive designs and their renewability due to the high level of chitinous tissue regeneration in this sponge. Recently, these biocompatible chitinous scaffolds have been successfully used in the tissue engineering of human mesenchymal stromal cells [1].

Methods

In this study, we investigated the characteristics of 3D microtubular I. basta sponge chitin, assessing its potential as a derived capillary system [2]. Various model liquids, including corresponding solutions of brilliant green (Fig.1), gentian violet, rivanol, iodine, potassium permanganate, decamethoxine, polyhexanide, as well as sea buckthorn oil and bromotyrosine—glycerin extract, were selected due to their antibacterial properties. The scaffolds, treated with these solutions, were evaluated against clinical Gram-positive and Gram-negative bacterial strains, as well as fungi.

Results

The results showed zones of growth retardation for brilliant green, gentian violet, decamethoxine, and polyhexanide solutions. Notably, chitin matrices impregnated with antiseptic solutions retained their antibacterial properties for more than 72 hours and effectively transmitted these properties to fresh microbial cultures.

Conclusions

The results with diverse antiseptics impregnated with chitin scaffolds demonstrate considerable potential as an innovative material for wound dressing applications and controlled drug release.

sciforum-086618: Biomimetic Synthesis of Lepidocrocite on Marine Spongin Scaffolds: Mechanistic Insights and Multifunctional Potential

Anita Kubiak [1,2], Martyna Pajewska-Szmyt [3], Martyna Kotula [1,3], Bartosz Leśniewski [1,3], Kamil Dydek [3] and Hermann Ehrlich [3,4]

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Introduction

In 1968[1], a significant milestone in marine biomineralogy was achieved through the observation of crystalline lepidocrocite mineral phases (γ-FeOOH) forming on the proteinaceous spongin fibers of marine demosponges. This finding laid the foundation for exploring the field of biomimetics, raising intriguing questions about the potential of marine sponges as a sustainable source of unique spongin-based 3D scaffolds suitable for the in vitro biomineralization of iron ions on and within their microporous surfaces[2].

Methods

Our recent advancements have employed cutting-edge biomimetic techniques to synthesize lepidocrocite in vitro on a spongin scaffold [3]. This research study explores the complex interaction between iron ions and the spongin scaffold in an artificial seawater environment, resulting in the development of a centimeter-large 3D iron–spongin composite. It is analyzed using analytical techniques including digital optical microscopy, scanning electron microscopy (SEM/EDX), high-resolution transmission electron microscopy (HRTEM), FTIR, X-ray diffraction, and confocal micro X-ray fluorescence spectroscopy (CMXRF).

Results

Our research reveals a likely mechanism for lepidocrocite formation, seemingly linked to the amino acid functional groups in spongin. Building on this insight, we developed an iron–spongin composite characterized by its porosity, macroscopic 3D structure, and magnetic properties, as confirmed by comprehensive analyses using various techniques. Moving beyond merely providing foundational knowledge, our study pioneers the application of this 3D composite as a dopamine sensor. This represents not just a breakthrough in sensor technology but also exemplifies the effective translation of a biological process into a practical engineering application.

Conclusions

We successfully synthesized the 3D iron–spongin composite in vitro, leveraging the unique properties of spongin and its interaction with iron. This innovative material demonstrates significant potential as a novel dopamine sensor, highlighting its broader applicability in fields such as environmental remediation, biomedical engineering, and electrochemical devices, thereby exemplifying the seamless integration of biomimetic research with practical engineering solutions.

sciforum-086696: Effect of Vitamin D3 Functionalization on Osteogenic Differentiation of Dental Pulp Stem Cells and Genotoxicity in Bioinspired 3D Scaffolds Based on Marine Sponge

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Introduction

Recent advancements in tissue engineering highlight the potential for 3D scaffold functionalization using biomolecules to induce specific actions within the material's microenvironment. Vitamin D3, a key biomolecule for bone tissue regeneration, plays a crucial role in modulating calcium and phosphorus absorption, supporting the functions of osteoblasts and osteoclasts. Insufficient levels of vitamin D3 can lead to the development of thin and brittle bones, while its anti-inflammatory properties and immune system modulation further emphasize its significance.

This study aimed to obtain 3D scaffolds functionalized with vitamin D3 based on sol-gel Cerium (Ce) doped mesoporous bioactive glasses (MBGs) and Spongia agaricina (SA), a natural marine sponge.

The research assessed the functionalized scaffold capabilities for in vitro osteogenic differentiation of dental pulp stem cells and their genotoxicity towards osteoblast cells.

Methods

The template replica technique was used for 3D scaffold preparation based on Ce-doped MBGs in the $70SiO_2$-(26-y) CaO-$4P_2O_5$-yCeO_2 system (y denotes 0, 1, and 3 moles) and SA as a sacrificial template. The green scaffolds were thermally treated in two stages up to the final temperature of 1200 °C.

The obtained scaffolds were analyzed by Scanning electronic microscopy (SEM) coupled with energy-dispersive X-ray spectroscopy (EDS), Fourier-transform infrared spectroscopy (FTIR), and microcomputed tomography (micro-CT). The effect of vitamin D3 functionalization on biological properties was also investigated by in vitro assays.

Results

Analysis using Micro-CT unveiled that all scaffolds displayed an interconnected porous structure, with pore diameters predominantly falling within the range of 143.5 to 213.5 μm, which can promote effective bone ingrowth. Vitamin D3 functionalization of the scaffolds promoted bioactivity and osteogenic differentiation of dental pulp stem cells, leading to increased secretion of calcium and osteocalcin.

Conclusions

The results showed that functionalized 3D scaffolds are safe, do not damage the DNA cells, and promote in vitro osteoinduction.

sciforum-086620: Extreme Biomimetic Approach: Melting of Steel and Copper on Carbonised 3D Spongin Scaffolds

Bartosz Leśniewski [1,2], Eliza Romańczuk-Ruszuk [3], Martyna Kotula [1,2], Anita Kubiak [1,2], Izabela Dziedzic [1,2], Martyna Pajewska-Szmyt [1] and Hermann Ehrlich [1,4]

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Introduction

Spongin is a naturally occurring renewable biopolymer originating from marine sponges. In cultivated bath sponges, spongin-based 3D skeletal constructs are characterised by thermostability up to 360 °C, elasticity, durability, porosity, flexibility, and compressibility. This unique biomaterial can be carbonised at temperatures over 1000 °C and transformed into graphite without losing its 3D architecture [**?**]. The aim of this study was to investigate the melting behaviour of steel and copper on the surface of carbonised spongin scaffolds.

Methods

Diverse types of steel in the form of shavings or powders as well as copper powder were melted on selected carbonised spongin templates in a furnace at temperatures of 1450 ºC/1600 ºC in an argon atmosphere for 90 min. The obtained phases were analysed using digital optical microscopy, SEM/EDS, and elemental mapping techniques.

Results

Due to the reaction of carbonised spongin with steel or copper during melting, novel, never before reported 3D composite materials were developed and characterised (Figures 1 and 2).

Conclusions

Due to the nanocrystalline metallic phase which is homogenously distributed on the surface of carbonised spongin, microfibres separated from the metallised 3D constructs show the appearance of magnetic properties only in the case of iron–spongin composites.

Figure 1. Stainless-steel 316 L powder after melting on carbonised spongin scaffold at 1450 oC for 90 min in an argon atmosphere.

Figure 2. Construction steel EN S235JRG2 (AISI 1015) after melting on carbonized spongin scaffold at 1450 oC for 90 min in an argon atmosphere.

Acknowledgments

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Reference

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sciforum-086078: The Use of Plant-Derived Biomaterials as Drug Formulation Excipients: An Application of Biomimetics in Dosage Form Development

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Introduction

To develop an active drug into a suitable dosage form, pharmaceutical scientists combine various excipients (additives) obtained from different sources. Considering the trends of advancements in the field of biomimetics, we hypothesize that biomaterials contained in different plant parts have inherent biological properties that can mimic what is desired of a drug excipient. In this project, the researchers seek to explore a range of plant-derived constituents and analyze them towards optimizing their use as pharmaceutical excipients in dosage form development.

Method

A range of desired pharmaceutical product qualities was selected to be the focus of the study. Following this, a comprehensive literature survey is being carried out to identify plant and herb parts with documented records of possessing these desired traits in their composition and biological activity. The availability of these plant parts in Africa was also considered. The identified plant parts will be collected, after which the constituents of interest will be extracted from them. These constituents will be characterized and optimized for the prospects of enhancing pharmaceutical formulations, leveraging their natural pathways of activity.

Results

The following dosage form properties have been identified as the primary considerations in this study: bioadhesion/mucoadhesion, disintegration, solubilization, binding, thickening, and taste enhancement. A literature survey is ongoing to determine what plants elicit these properties in their natural life cycles. The outcome of this literature exploration will guide the plant procurement and extraction phases.

Conclusion

Driven by the possibility of having plant constituents replicate their biological characteristics upon incorporation in pharmaceutical dosage forms, this study expects to generate usable biomimetic-derived drug excipients in a bid to make final pharmaceutical products more affordable and therapeutically effective.

sciforum-086604: Utilizing Passive Radiative Properties of Silver Ants

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The increasing occurrence of hot summer days causes stress for both humans and animals, particularly in urban areas where temperatures remain high, even at night. Nature offers potential solutions that require minimal energy and material costs. For instance, the Saharan silver ant can endure the desert heat by means of passive radiative cooling induced by its triangular hairs. Shi et al. experimentally demonstrated this effect. The aim of this project is to transfer the structural cooling property of the Ant to various surfaces using an epoxy mould or stamp. Shrimp shells are chosen as the first target surface due to their low cost (as a waste product), biodegradability, and similarity in material to the ants' bodies (Chitin).

In the initial phase of the project, shrimp shells are scratched with a diamond tip. Some of the samples are subjected to simulated hot and cold climates inside a climate chamber for three weeks. Comparing the exposed to the unexposed samples provides insight into the weatherability of the shells. The measurements are carried out with optical, confocal, and electron microscopy.

In the second part, a stamp of the silver ant's surface is manufactured using the process described in the paper by Zobl et al. This stamp is used to modify the shrimp shell surface, with the aim of increasing its emissivity. We want to show that it is possible to decrease the surface temperature purely through functionalities induced via structural modification. This shall then be scaled up for larger surfaces, such as house facades, to reduce the need for conventional cooling.

sciforum-087687: Engineering Multifunctional Biomimetic ECM Proteins with Elastin-like Polypeptide Fusion for Enhanced Tissue Regeneration

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The study aimed to address the challenge posed by the large molecular weight of natural extracellular matrix (ECM) proteins in fabricating functional structures suitable for tissue repair. To overcome this, a low-molecular-weight and multifunctional chimeric recombinant ECM was engineered by fusing elastin-like polypeptide with various proteins to effectively stimulate mesenchymal stem cells (MSCs) for tissue regeneration. The rationale for establishing the fusion with elastin-like polypeptide was to enhance the bioactivity and functionality of the ECM proteins. Control studies with the proteins alone were conducted to assess the impact of elastin-like polypeptide fusion on cellular responses.

Additionally, the bio-functionalization of titanium surfaces with recombinant fibronectin and elastin-like peptide was utilized to enhance bioactivity for improved osseointegration. This biofunctionalization sustained bioactivity over a 4-week period without an initial burst effect and notably increased the adhesion, proliferation, and osteogenic differentiation of human mesenchymal stem cells (hMSCs). The biomimetic fibronectin-coated titanium surfaces further induced the elevated expression of osteogenesis-related genes, emphasizing its potential to promote bone regeneration.

Control studies with individual proteins and without elastin-like peptide fusion were conducted to evaluate the specific contribution of the fusion strategy to cellular responses. The results demonstrated significantly increased cellular activities and osteogenic differentiation on the biomimetic fibronectin-coated titanium compared to non-coated surfaces, highlighting the beneficial effects of elastin-like polypeptide fusion for enhancing tissue regeneration outcomes. In summary, the rationale for fusing elastin-like polypeptide to ECM proteins in this study is to leverage ELP's unique properties to enhance the biomimicry, solubility, stability, purification efficiency, controlled release, and overall bioactivity of recombinant ECM proteins for improved tissue regeneration applications. The fusion strategy offers a promising approach to overcome challenges associated with large-molecular-weight ECM proteins and optimize their therapeutic potential.

sciforum-089515:From the Insect Adhesion to Snake Slithering: Tribology and Contact Mechanics Aspects of Biological Surfaces

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Introduction

For attachment and propulsion generation during locomotion, different surface adaptations have been evolved in the course of animal evolution. Some of these structures have been well structurally studied, but their functional mechanisms, based on the interplay between the ultrastructure, material properties and physical interactions remained unresolved until recently. The reason for this is that such research requires approaches of several disciplines: zoology, structural biology, biomechanics, physics, and surface science. In addition to the use of a wide variety of microscopy techniques, we established a set of experimental designs that allows obtaining information about adhesive and frictional properties, as well as local and global mechanical properties of materials of animal attachment devices (part 1) and belly surface of the snake skin (part 2), in order to understand tribological mechanisms behind these biological surfaces.

Attachment: Flies, Spiders, Geckos on the Ceiling

In order to show different functional principles, we experimentally tested about 600 different locomotory attachment devices on legs of insects (Figure 1), spiders and geckos and tried to outline general rules of the interrelationship between their structure and function. Since these broad comparative studies include a wide variety of organisms, some questions about the evolution of these systems could be resolved.

Snake Skin Tribology

Owing to the lack of extremities, the ventral body side of snakes is in almost continuous contact with the substrate. In spite of this, snakes are one of the most successful animal groups in occupying various ecological niches. From a tribology point of view, their ventral skin surface has to fulfill two opposite functions: (1) to support body propulsion during locomotion by generating high friction in contact with the substrate and (2) to reduce skin material abrasion by generating low friction in forward sliding along the substrate.

Abstracts

Session 6. Biomimetic Application of Insect Functional Morphology

sciforum-089524: Functional Morphology Studies on the Cuticle of Spherical Shape Beetles

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Most insects have an elongated shape and can be divided into two main geometric sides: the dorsal and the ventral. However, in some insect groups, such as Chrysididae (Hymenoptera), Cybocephalidae, Clambidae (Coleoptera), and Blaberidae (Blattoidea), a similar spherical shape has independently evolved, with the dorsal side becoming the external side. The cuticle is the most important modified part in spherical insects. To investigate the morphological and functional differences in the cuticle between elongate and spherical insects, three beetles from the superfamily Scarabaeoidea were studied: one spherical insect from Ceratocanthinae and two elongate insects from Hybosorinae and Melolonthinae.

The morphological comparison shows that the dorsal cuticles (e.g., pronotum and elytra) are expanded and curved in the spherical beetles, and additional joints between the cuticles help to maintain the basic shape. Uniaxial compression tests indicate that spherical beetles have greater overall defensive strength. Since the defensive strength of the exoskeleton is affected by both the dimensions (material thickness) and the mechanical properties of the material, CT scans and nanoindentation tests were performed to evaluate these two factors. The results showed that the average cuticular thickness of spherical insects was the highest, and the variation in thickness between different parts of the body cuticle was greater than that of the elongated ones. The elastic moduli of the outer cuticle parts (pronotum and elytra) of Ceratocanthinae were significantly higher than those of other beetles.

In conclusion, the findings show that the cuticles of spherical beetles not only changed their shape, but also exhibited higher stiffness and thickness, supporting the overall higher defensive strength. Further studies on the structures of exocuticles and endocuticles could provide additional information about this strategy. This work helps to explain the evolution of spherical insects and may inform the biomimetic design of spherical robots.

sciforum-089572: Full Cocoon vs. Cut and Flattened Walls: Comparing Stab Testing Methods as Applied to *Bombyx mori* Silk Cocoons

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The *Bombyx mori* silk cocoon serves as a protective covering around the pupa; its mechanical construction should therefore be resistant to predatorial attacks such as punctures, perforations and tears. The *B. mori* cocoon's resistance to such modes of damage is nevertheless still largely undocumented. The work presented here is part of a broad endeavour to describe the damage tolerance of *B. mori* silk cocoons. Here, we evaluate two different testing methods using an Instron-3369 testing apparatus to determine its resistance to stabbing by an HOSDB-standard knife. In the first method, the cocoon is stabbed through in its entirety (i.e., through an uncut and unimpaired structure), while in the second approach, the cocoon is cut open to form a rectangular quasi-flat sheet of cocoon wall which is tightly clamped prior to being punctured by the knife stab. The stabbing force was measured in both techniques. While the stabbing forces needed to puncture and perforate full cocoons and rectangular walls were approximately the same, there were noticeable differences in the force vs. extension curves in each stabbing method. The analysed results imply that it is preferable to directly test full cocoon walls rather than to artificially pre-prepare the cocoon wall into quasi-flat sheets and to then forcibly constrain them at specific edge locations of the quasi-flat sheet. This is because the artificial pre-preparation of cocoon walls forces them to adopt an unnatural geometrical form (quasi-flat) and, as a consequence, the wall deforms in an unnatural manner during the penetration stage of stabbing. This is an important finding since the vast majority of the mechanical testing research published utilises cut and quasi-flattened cocoon walls. There is currently no standardised test method for the puncture and perforation of material from *B. mori* cocoons. In conclusion, our research provides new insights into their preparation and testing.

sciforum-086600: Microstructure and Hydrophobicity of the Wing Surface of Some Moths

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Introduction

Aquatic moths of Lepidoptera, Crambidae, and Acentropinae inhabit moist environments. For example, the larvae of genus *Eoophyla* all live in streams, and their wing surfaces are highly hydrophobic after a long period of evolution. Currently, there are only some sporadic reports on the classification and agricultural control of aquatic moths, and reports on hydrophobic properties and their surface scales are very limited.

Methods

We used a contact angle measuring instrument and SEM to study the hydrophobicity and microstructure of three aquatic moths *Eoophyla ochripicta*, *E. menglensis*, and *E. melanops* (Crambidae, Acentropinae) and a non-aquatic moth *Conogethes punctiferalis* (Crambidae, Pyraustinae).

Results

Our research results show that the wing surfaces of all three aquatic *Eoophyla* moths have strong hydrophobicity, and the contact angle of the minimum water drop volume was 15 μL (ranging from 139.3° to 143.0°), but the contact angle of the non-aquatic moth was only 133.9°. The microstructures of the wing surfaces of the three aquatic *Eoophyla* moths are similar: the surface of the scales consists of sub-micron longitudinal ridges and laterally connected ribs, and the spacing between the longitudinal ribs is 0.8~1.69 μm, exhibiting a grid shape. Conversely, the laterally connected ribs of *C. punctiferalis* are incomplete.

Conclusions

Due to the presence of the wing surface microstructure of aquatic moths, and because the scale of the structure is much smaller than the diameter of the droplet, this leads to the formation of air pockets under the droplets, which are unable to fully fill the grooves of the surface. Thus, the wing surface exhibits stronger hydrophobicity. However, the microstructure of *C. punctiferalis* can make water droplets have more contact with the wing surface, so the hydrophobicity is less favorable than that of aquatic *Eoophyla* moths. Researching the relationship between the hydrophobic properties of the wing surface and its structure can provide an experimental and theoretical basis for the preparation of hydrophobic biomimetic materials.

sciforum-086630: Modularity in the Insect World as a Strategy for Bio-Inspired and Sustainable Design

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The morphological and functional diversity of insects provides a valuable source of inspiration for the bio-inspired design of innovative and sustainable products and processes. This paper proposes to examine the principles and strategies that guide nature's evolutionary and adaptive activities, with a focus on the concept of a "module" as a measure and standard for achieving resilience and sustainability in natural ecosystems. The concept of a module, relevant in all living organisms, is particularly evident in insects: redundant and hierarchical geometries capable of generating high and unprecedented performances, such as, for example, the structural color observed in Chrysina Gloriosa, the superadhesion capacity observed in Hydaticus Pacificus, and the thermoregulation and structural strength of the Odonata dragonfly.

Modularity in insect structures manifests itself at different scales of observation, from nano to micro and macro scales, and at different levels, including morphology, structural organization, mechanisms of functioning, and behavioral processes. Emulating the principles and strategies of inherent modularity in insects in the design of processes and products can significantly contribute to increased sustainability, introducing new perspectives in the field of design for environmental sustainability in synergy with bio-inspired design.

Examples of insect morphological/functional diversity will be analyzed and related to case studies of bio-inspired designs and products, and the advantages gained in imitating some of their aspects and characteristics will be made explicit. In addition, it will be highlighted how computational design—that is, the application of algorithmic and systems thinking through the use of analysis tools, generative modeling, and 3D printing—enables the replication of complex forms by imitating the modularity present in insects, which, in different aggregations, generates resilient, sustainable, and well-performing structures.

sciforum-089585: Relationship between Structure, Mechanical Properties and Function in Locust Cuticle

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The insect cuticle is a multifunctional biological material. One of its striking characteristics is the wide range of its mechanical properties. The elastic modulus of insect cuticle, for example, covers a range of more than eight orders of magnitude [1]. Why do cuticle properties vary so dramatically? To address this question, researchers have used a set of different testing methods to measure the properties of cuticle specimens, which have been selected from various body parts across a variety of insect species and often preserved/prepared in different ways [2,3]. However, almost all these factors can influence the obtained data. Hence, the literature data cannot be simply compared with each other, and no solid conclusion can be drawn regarding the mechanisms that underlie the property variations in the cuticle. To fill this gap in the literature, our studies are focused on two key questions. First, how do the mechanical properties of insect cuticle differ in a single species when all testing conditions are kept constant? Second, what are the mechanisms behind the wide range of cuticle properties? Using a combination of scanning electron microscopy (SEM), micro-computed tomography (micro-CT), confocal laser scanning microscopy (CLSM) and nanoindentation, we performed one of the most comprehensive studies to date, where we simultaneously investigated the microstructure, sclerotization and the elastic modulus of locust cuticle from different body parts. We have shown that, in the desert locust *Schistocerca gregaria*, the elastic moduli of tibiae, femora and compound eyes range from 0.5 GPa to 8 GPa [4–7]. This property change can be explained almost fully by the differences in the microstructure and sclerotization of the investigated specimens. We expect that our results will help to better understand the complex structure–material–function relationship in insect cuticle. In addition, the detailed data obtained might be potentially interesting for the biomimetic development of strong composite materials for various applications.

sciforum-089463: Research on the Flight Characteristics of Beetles and the Design of Bionic Aircraft

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The flying wing of the beetle exhibits unique wing spreading–flying–collecting behavior in the process of flight, which is the best bionic object for flapping wing aircraft design. In this paper, through the motion behavior observation system, the behavior analysis of beetle spreading–flying–unfolding wings is carried out, the kinematic parameters of the whole flight process are obtained, and the flow field visualization of the above behavior is studied using the smoke line method. During the flapping process, the flying wing of the beetle is spread out one by one in two stages, and the wingtip trajectory is in the shape of "W" when the wing is folded. The unique microhair structure on the sheath wing can provide sufficient friction to facilitate the folding of the flying wing. When flying, the wingtip trajectory of the beetle is in the shape of "8", and the flying wing is deformed in the process of downstroke and supination, which provides additional unsteady lift for the beetle flight. The enhanced leading edge vortex and surrounding leading edge vortex produced during the upstroke and downroke further reveal the unique high-lift mechanism of beetle flight. Based on the above research on the flight mechanism of the beetle, a flapping-wing aircraft imitating the beetle is designed.

sciforum-086613: Structural Regulation of Infrared Radiation in Butterfly Wing Scales

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The diversification of the periodic ultrastructure of wing scales plays a crucial role in regulating the functional properties of butterfly wings, contributing to their ecological adaptation. This study addresses the structural regulation of mid-infrared radiation (MIR) in wing scales, a property associated with cooling in thermoregulation and pheromone release during courtship. Using Danainae (Papilionoidea: Nymphalidae) as the model group, the study confirms the high morphological diversity of butterfly wing scales in a single individual with quantitative observations under scanning and transmission electron microscopy. It was found that this diversity shapes the heterogeneity of the wing emissivity through heating experiments, virtual simulations, and correlation tests. Summarizing the effects of each component on emissivity, it was demonstrated that the increase in scale emissivity is due to the increase in its internal surface area and thickness. Additionally, it was demonstrated that, as the structural parameter positively correlates with emissivity increases, the area of scent patches, a high emissivity region where males emit pheromones, decreases significantly, whereas the size of scales on the scent patch increases significantly. A further study of 99 butterfly species from several families shows that as the range of butterfly species moves from low to high latitudes, which generally corresponds to a decrease in habitat temperature, the efficiency of infrared radiation in the wing scales decreases, i.e., the wing radiates less efficiently for cooling and less heat is dissipated. This phenomenon is also shaped by variations in the overall structure of the scales. The study provides a reference for understanding functional adaptation in butterflies.

sciforum-086828: The Unique Flight Strategies Adopted by Butterflies When Landing on Vertical Surfaces

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Landing on vertical surfaces poses a greater challenge for insects compared to horizontal ones, yet it remarkably expands their spatial range. Butterflies, adept at perching vertically, offer a compelling bio-inspired model. However, the mechanisms behind their landing behavior and the associated perceptual processes on vertical surfaces remain elusive. Similar to takeoff, understanding the distinctive strategies employed by butterflies during vertical landings is imperative. This encompasses the dynamics of self-stability, the role of visual perception in posture control, and the influence of asymmetric wing flapping on posture changes. This research employs a high-speed camera system to comprehensively track the descent process of butterflies onto vertical surfaces. This study successfully captures a sequence of coordinated behaviors involved in wall landings. Kinematic analysis reveals the ability of butterflies to maintain body stability despite significant pitch rate variations. This suggests that, beyond flight mechanics, butterflies exhibit robust control over body posture influenced by other factors. Drawing on insect optic flow perception during landing, this study proposes three primary visual cues influencing butterfly landing behavior. Correlation analysis establishes connections between butterfly rotational maneuvers and visual cues. Finally, by delineating the asymmetrical differences in wing Euler angle changes, the corresponding relationships with posture angle variations are identified.

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