Sectional Committee -V

Engineering and Technology

Chair
Prof. Yogesh M Joshi, FNA

Dr. Yogesh Joshi earned his B.E. from Pune University in 1996 and his Ph.D. in Chemical Engineering from the National Chemical Laboratory Pune and the Indian Institute of Technology Bombay in 2001. He then joined the Benjamin Levich Institute in New York for post-doctoral studies. In 2004, Dr. Joshi joined the Department of Chemical Engineering at the Indian Institute of Technology Kanpur, where he is currently the Sir J C Bose National Fellow and Mr. and Mrs. Gian Singh Bindra Chair Professor. His research interests include the rheology of complex fluids, soft matter, interfacial science and engineering, clay dispersions, and polymer science and engineering. He is a senior editor of Langmuir and serves on the editorial advisory boards of Physics of Fluids, Journal of Rheology, and Rheologica Acta. Dr. Joshi received the prestigious Shanti Swarup Bhatnagar award in Engineering Sciences in 2015. He is an elected fellow of the Society of Rheology (US), the Indian National Science Academy, the Indian National Academy of Engineering, and the National Academy of Sciences, India.

INSA Distinguished Lecture

Limitations for quantum search by circuits of limited quantum depth

Jaikumar Radhakrishnan

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We consider algorithms for quantum search with limited quantum depth, that is, algorithms where all the registers are measured after every k queries to the oracle. We provide an information-theoretic proof that any such algorithm to find a marked element in a database with n elements requires Omega(n/k) queries. The lower bound will be obtained by combining considerations of quantum fidelity with a chain rule for Hellinger distance due to TS Jayram. The lower bound itself is not new: it was established by Hamoudi, Liu and Sinha (2023) using sophisticated and more generally applicable machinery that they developed for studying noisy circuits for collision finding. (This is based on unpublished joint work with Rohit Sarma Sarkar.)

Speaker's Profile

Jaikumar Radhakrishnan is a theoretical computer scientist with research interests in complexity theory, randomness and computation, quantum information and computation, combinatorics, and information theory. Radhakrishnan obtained his BTech in Computer Science and Engineering from IIT Kharagpur in 1985, and his PhD in Computer Science from Rutgers University, NJ, USA, in 1991. He joined the Tata Institute of Fundamental Research in 1991; in 2024 he moved to the International Centre for Theoretical Sciences (ICTS-TIFR), Bengaluru, where he is currently a Distinguished Professor.

INSA Distinguished Lecture

From Benchmarks to Models: Building the Foundation for Inclusive AI in Indian Languages

Sriparna Saha

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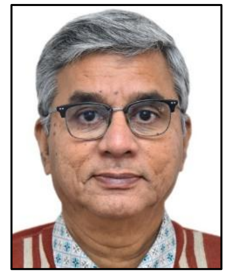
Benchmarking large and multimodal language models across cultural, multilingual, and healthcare domains is a pressing need. Before deploying these models, it is vital to understand their robustness across diverse tasks. My research began with evaluating AI systems' understanding of India's cultural and linguistic diversity, leading to the creation of two major benchmarks: SANSKRITI and DRISHTIKON. SANSKRITI comprises over 21,000 curated question–answer pairs across 28 states and 8 union territories to assess cultural competence, while DRISHTIKON includes 64,000 text–image pairs in 15 Indian languages, enabling culturally grounded multimodal evaluation. These benchmarks revealed the underrepresentation of Indian languages and contexts in AI, motivating expansion into new domains. CultSportQA evaluates AI reasoning in traditional sports across 60 countries, promoting culturally aware global reasoning. M3LS, the largest multilingual multimodal summarization dataset spanning 20 languages, supports standardized evaluation of summarization from text and images. COSMMIC integrates articles, images, and reader comments for comment-aware summarization in nine major Indian languages. Collectively, these resources advance inclusive, context-aware, and culturally competent AI evaluation. Building on these, we are developing Small Language Models (SLMs) tailored for Indian languages and culturally grounded tasks. In healthcare, we built a small domain-specific model for veterinary medicine, trained with pretraining, fine-tuning, and safety alignment. Complementing this, M3Retrieve offers a multimodal medical retrieval benchmark with 1.2 million documents and 164K queries, and a multilingual trust benchmark spans 15 languages and 18 tasks. Together, these efforts aim to make generative AI robust, reliable, and inclusive for culturally rich and healthcare applications.

Speaker's Profile

Dr. Sriparna Saha received her M.Tech. and Ph.D. degrees in Computer Science from the Indian Statistical Institute, Kolkata. She is currently an Associate Professor in the Department of Computer Science and Engineering, Indian Institute of Technology Patna. Her research interests span natural language processing, generative AI and multimodal learning. Dr. Saha has received numerous recognitions, including the INSA Young Associate (2024), NASI Young Scientist Platinum Jubilee Award, Fulbright-Nehru Fellowship, and the Humboldt Research Fellowship. She has also received multiple Best Paper Awards at prestigious international venues and serves on the editorial boards of several IEEE and ACM Transactions journals.

Hybrid materials as electrode and electrolyte materials for conversion devices



Suddhasatwa Basu

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Developing a low-cost effective, readily available, highly efficient electrocatalyst and electrolyte are essential to produce clean and sustainable energy through electrochemical energy storage and conversion devices. The *bi*-functionalized Fe, Co, Ni phosphonates based electrocatalysts have been used for overall water splitting in an alkaline medium due to its higher surface area with microporous channel and the synergistic effect of the highly active metal oxyhydroxide component on the pore wall leading to lower activation overpotentials [Electrochim Acta, 2022 416, 140277]. A 3d-printed membraneless microfluidic electrolyzer (μE) is developed with 1 A/cm^2 current density at 2.4 V [Chem. Eng. J., 2023, 452 (3), 139433]. Further, polyanionic compound, e.g, $Na_3V_2(PO_4)_2F_3$ (NVPF), which suffers from the intrinsic drawbacks of poor electronic conductivity, limited reversible capacity, and severe volume alterations during intercalation-deintercalation cycling in Na-ion battery, is coated with boron doped carbon (BDC) to bring synergistic contribution of morphology and surface modulation on the electrochemical activity of NVPF/BDC electrode. In another example, a protective layer ZIF 8 based MOF on the zinc anode has proven to be an effective approach for aqueous zinc-ion batteries slowing down dendrite formation. We have worked on development of all solid-state cobalt free Li-ion battery in collaboration with Bar-Ilan University, which is based on $LiNiO_2$ (LNO) cathode coated with $LiAlZnO_2$ (LAZO) protective layer of 4 nm thickness along with argyrodite solid electrolyte which is safe and durable [3]. LAZO@LNO-based ASSLB deliverred a high specific capacity of 4.65 mAh·cm^{-2} (184.48 mAh·g^{-1}) and 4.14 mAh·cm^{-2} (159.5 mAh·g^{-1}) with a good capacity retention of 81.46% after 60 cycles and 70.31% after 200 cycles at a current density of 0.454 mAcm^{-2} and 0.934 mAcm^{-2}, respectively [[Nat Nanotech, 2024, 19, 208–218]. Further, Nd-based perovskites $Nd_{0.67}Sr_{0.33}Co_{0.8}Fe_{0.2}O_{3-\delta}$ (NSCF) have been developed as an efficient IT-SOFC cathode, which exhibits outstanding power densities of 1.52 W/cm² at 700°C [Small, 2025, 21, 240896].

Speaker's Profile

Prof. Suddhasatwa Basu completed Ph.D./MS in Chemical Engineering from Indian Institute of Science, Bangalore. He holds FIPI Chair Professor on Clean Energy at IIT Delhi. Earlier, He was the Director of CSIR-Institute of Minerals & Materials Technology, Bhubaneswar. He has vast work experience on development of materials for energy conversion and storage devices, e.g., Hydrogen & Fuel Cells Technologies and Li-/Na- Ion Battery, Electrosynthesis. He has published more than 290 articles in high impact journals with H-index 56, 10 granted patents and 6 filed, and 2 technologies transferred to industries. He is a Fellow of Indian National Science Academy (designated), National Academy of Science of India, Indian National Academy of Engineering, Royal Society of Chemistry UK and received Fulbright fellowship, Herdillia Award, Dr A. V. Rama Rao Foundation's Research Award, SMC Gold Medal, MSRI Medal.

Rising from ashes like the phoenix, nanofluids: providing breakthroughs in thermal management and beyond

Sarit K Das

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At the beginning of the millennium, Nanofluids, which are dilute suspensions of nanoparticles in Newtonian liquids came with a huge promise in the arena of thermal management technologies. The relentless miniaturization and increasing power densities of electronic devices pose significant thermal management challenges. Nanofluids were seen as a significant emerging technological innovation to tackle these challenges. However, some controversies regarding stability and the quantum of property enhancement had put breaks on its progress towards full potential of its usage. In reality, the above discrepancy arises from the lack of standardization in the method of preparation. Of late, Nanofluids have made a strong comeback proving its decisive edge over usual cooling fluids in as diverse fields as cooling of electronics, Battery Thermal Management Systems (BTMS), and even hyperthermia treatments for tumor ablation. This lecture traces this development and also demonstrates the application of Nanofluids in a particular case of processing electronic material. Nanofluids, engineered by dispersing nanoparticles such as hBN in unique Deep Eutectic Solvents (DES), exhibit superior thermal properties. Furthermore, innovative geometries, such as mini-channel heat sinks with optimized flow features, can further enhance heat dissipation by promoting efficient heat transfer mechanisms. Choosing the right cooling method with environmental consideration is mandatory in the current global warming scenario. The current organic solvents replacing the presently used harmful engineering fluids will reduce the global warming potential (GWP) rating.

Speaker's Profile

Prof. Sarit K. Das, Institute Professor at IIT Madras and first V. Balakrishnan Chair occupant, is a former Director of IIT Ropar. A leading expert in nanofluids, his research spans thermo-fluidics, BTMS, fuel cells, and bio-microfluidics. He is a Fellow of NASI, INAE, Humboldt Foundation, Asian Union of Thermal Sciences and Engineering (AUTSE), and a JC Bose awardee. A Peabody Professor at the Massachusetts Institute of Technology (2011), he received the India Citation Award (2012) and IIT Madras Lifetime Achievement Award. He is an associate editor of Heat Transfer Engineering. He received the Lifetime Achievement Award from IIT Madras.

Shocking - Yet True…

G. Jagadeesh

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The phenomenon of "Shock Waves" has been historically associated with aerospace engineering and in particular with supersonic flight. Shock waves appear in nature, when different elements in a fluid approach one another with a velocity higher than the local speed of sound. These waves are also generated if massive energy dissipation takes place within ultra-short time in events like explosions. A number of methodologies/facilities to generate shock waves of requisite strength have been designed and indigenously built in the Laboratory for Hypersonic and Shockwave Research (LHSR) in Indian Institute of Science (IISc), Bangalore. Over the years, these facilities have facilitated very interesting interdisciplinary research programmes in IISc with participation of several faculty members from physics, chemistry, biology and materials engineering. Some of the novel techniques that will be discussed in this talk includes retractable aero-spikes, smart coatings, forward facing jets and concentrated energy deposition for reducing the aerodynamic drag around vehicles flying at hypersonic speeds. Concurrently, utilizing the remarkable ability of shock waves to instantaneously enhance the pressure and temperature in the propagating medium, several innovative shock-wave assisted techniques have been developed in LHSR. These include non-intrusive needleless vaccine delivery, cell transformation, Wound healing in diabetic patients, bio-film destruction, polyphenol enrichment in tea, metal texture modification, and preservative impregnation in bamboo. A broad overview of the recent Transdisciplinary shock wave science and technology development activities at LHSR will be presented in this lecture.

Speaker's Profile

Prof. Gopalan Jagadeesh is a Senior Professor in the Department of Aerospace Engineering, and the Founder Chairman of Centre of Excellence in Hypersonics, in IISc, Bangaluru. He mentors many start-ups formed with equity participation from IISc to commercialize several of his discoveries related to shock waves and allied areas. Prof. Jagadeesh is one of the leading researchers in Hypersonic Aerothermodynamics and shock wave propagation in complex fluids. He has published extensively in addition to holding 25 patents on various discoveries related to Shock Waves and hypersonic flow control. He is currently the President of the International Shock Wave Institute, Sendai, Japan. He is a Fellow of the prestigious Royal Aeronautical Society (UK), Indian Academy of Sciences, National Academy of Sciences and National Academy of Engineering. Prof. Jagadeesh is very passionate about spreading scientific temper especially among rural high school/college students in India and has interacted with over 600,000 till date.

INSA New Fellow Lecture

Designing Durable Liquid-Infused Surfaces for Liquid Food Packaging

Suhas S Joshi[a,b]

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Adhesion of sticky liquid foods such as honey, ketchup, and yoghurt to packaging surfaces leads to product wastage and poses challenges in cleaning and recycling. Bio-inspired by the Nepenthes pitcher plant, Liquid-Infused Surfaces (LIS) offer a practical solution to minimize residue through a stable, immiscible lubricant film entrapped within textured cavities. However, the durability of LIS depends strongly on texture geometry and lubricant properties. Flow-based simulations across four cavity shapes identified the rectangular cavity as the most robust geometry for lubricant retention under shear in laminar flows, exhibiting minimal depletion across viscosity ratios ($0.2 \leq \mu_r \leq 1.0$) and Reynolds numbers ($100 \leq Re \leq 1000$). Under low-frequency oscillations (0.1–10 Hz) representing transport vibrations, stability improved for denser lubricants and more viscous external liquids, while oscillation amplitude showed negligible influence. The findings were experimentally validated on stainless-steel substrates textured with femtosecond-laser 2D pillars bearing LIPSS and infused with silicone oils of 5 cSt, 20 cSt, and 100 cSt. Results with honey (Newtonian) and four shear-thinning foods: mango juice, cold coffee, ketchup, and yoghurt, showed low critical sliding angles (<32°). Increasing lubricant viscosity systematically enhanced durability; higher-viscosity LIS shed more drops with minimal residue after repeated cycles, while immersion tests confirmed sustained repellency and lubricant retention. Overall, rectangular-cavity LIS with viscous lubricants provide a robust and scalable design for sustainable food packaging and open pathways for large-scale applications in cosmetic and pharmaceutical containers.

Speaker's Profile

Dr. Suhas Joshi is currently the Director, IIT Indore. He is a Fellow of the Indian National Academy of Engineering (INAE), the National Academy of Sciences of India (NASI), and The American Society of Mechanical Engineers (ASME). Prior to joining IIT Indore as the Director in Jan 2022, at IIT Bombay, Dr. Joshi was Rahul Bajaj Chair Professor (2014-22). He also served as the Dean of Alumni and Corporate Relations (2018-22) and the Head of Mechanical Engineering Department (2014-17). Dr. Joshi obtained his Ph.D. from IIT Bombay in 1997 and worked with Engineering Research Centre of Tata Motors, Pune before joining IIT Bombay as a faculty member in 1999. Dr. Joshi was a Research Affiliate at Georgia Tech, USA while pursuing post-doctoral research supported by BOYSCAST Fellowship of Govt. of India in 2002. He was a Visiting Faculty at the University of Illinois at Urbana-Champaign, USA during 2005-06. During 2009-14, he spearheaded establishment of 'National Centre for Aerospace Innovation and Research (NCAIR)', at IIT Bombay as its founding Principal Investigator. The centre was an industrial consortium mainly supported by Govt. of India and The Boeing Company. Dr. Joshi's research work involves improving the productivity and quality of multi- scale machining processes through physics-based modelling. He has undertaken over 35 research, consultancy, and infrastructure development projects sponsored by aerospace, nuclear, defence organizations and industries. Dr. Joshi has several editorial assignments with prestigious international journals during all these years. Dr Joshi received Dr. P. K. Patwardhan Technology Development award (2008) and Best Faculty award of Mechanical Engineering Department (2007) at IIT Bombay. Dr. Joshi has supervised 4 post-doctoral and 24 doctoral students. He is currently guiding 2 Ph.D. students. He also has supervised more than 120 masters' dissertations. Dr. Joshi has around 360 publications including over 210 in refereed international journals.

INSA New Fellow Lecture

Artificial Intelligence and Machine Learning for Healthcare Systems

Ujjwal Mauliks

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Kolkata-700032

In this lecture, first the fundamental, current trends and challenges in Artificial Intelligence (AI) and Machine Learning (ML) will be discussed. The basic concept of supervised, unsupervised and Deep Learning (DL) algorithms will be presented. We will also learn the utility of explainable and trusted AI. In the second part of the lecture, we will present how advance ML techniques and Graph Algorithms can be used to build better healthcare system. In this regard, we will demonstrate the use of DL as well as Graph Neural Network (GNN). We will also discuss the challenges faced by a newly developed startup in this domain. Finally, we will conclude by presenting the future advancement of AI and ML.

Speaker's Profile

Dr. Ujjwal Maulik is a Professor in the Dept. of Comp. Sc. and Engineering., Jadavpur University since 2004. He was also the former Head of the same Department. Dr. Maulik has worked in many universities and research laboratories around the world as visiting Professor/ Scientists. including USA, Germany, France, Australia, China, Italy, Poland and Slovenia. He is the Fellow of INAE, NASI, IAPR, AAIA, IEEE. He has also received Humboldt Fellowship, Germany and Senior Associateship of ICTP, Italy. His research interest include Machine Learning, Pattern Analysis, Data Science, Bioinformatics, Multi-objective Optimization, Social Networking, IoT and Autonomous Car. In these areas he has published ten books, more than three hundred fifty papers, mentoring several start-ups, filed several patents and already guided twenty five doctoral students.

Mechanical behavior and oxidation resistance of materials tailored for ultra-high temperature aerospace applications

Rahul Mitra

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The rapid technological growth of aerospace sector in recent years has driven the development of materials for use under extreme environments at temperatures beyond the limit of nickel based superalloys. In this context, molybdenum (Mo) and niobium (Nb) silicide based refractory intermetallic alloys as well as the carbon fibre reinforced silicon carbide (C_f-SiC) composites are considered candidate materials to increase the operating temperatures of aero-engines, whereas the ZrB_2-SiC based ceramic composites are attractive for potential applications in nose-cones and leading edges of hypersonic vehicles. These materials are designed to retain strength and resist environmental degradation at high temperature, as well as exhibit adequate fracture toughness at room temperature. Ductile phase toughened Mo-Si-B and Nb-Si alloys are found to exhibit impressive strength retention along with high temperature oxidation resistance, with significant improvement caused by suitable alloying additions. The oxidation resistance of both Mo-Si-B alloys and ZrB_2-SiC composites is contributed by formation of a self-healing borosilicate glass scale. In ZrB_2-based composites, 20 vol% SiC reinforcement leads to an optimum resistance to oxidation, thermal shock and ablation, while the fracture toughness remains poor. The C_f-SiC composites designed with Si-B-C modified matrix and weak interphase of multi-layered $(PyC\text{-}SiC)_n$ exhibits increase in strength with temperature along with improved fracture toughness and damage tolerant behavior due to crack bridging by partially debonded fibres. Enhanced ablation resistance without compromising the damage tolerance is obtained in hybrid C_f-ZrB_2-SiC composites processed by infiltrating ZrB_2-SiC slurry into C-fibre preforms. Selected experimental results along with the involved mechanisms will be discussed.

Speaker's Profile

Prof. Rahul Mitra is a Professor of Metallurgical and Materials Engineering at IIT Kharagpur, where he joined after serving as scientist at DMRL, Hyderabad during 1993-2002. He received B.Tech (Hons.) in Metallurgical Engineering from IIT Kharagpur in 1988 and Ph.D. from Northwestern University, USA in 1992. His research is primarily focused on refractory intermetallic alloys and ceramic-matrix composites for ultra-high temperature applications. He has authored/co-authored 220 journal papers, 13 book-chapters, and 2 books. He is fellow of INAE, NASI, IIM and EMSI, while his awards include MRSI Medal, Metallurgist of the Year, GD Birla Gold Medal, and Faculty Excellence award.

INSA New Fellow Lecture

Emerging Semiconductor Heterostructures for Optoelectronic and Neuromorphic Devices

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We shall discuss the characteristics of 2D materials and perovskite nanocrystals based hybrid heterostructures for optical and neuromorphic devices. We noted a significant improvement in hot carrier relaxation dynamics, with a larger bi-exciton redshift in Cu-doped $CsPbI_3$ nanocrystals, leading to higher intraband recombination time. Hybrid heterostructures comprising of zero-dimensional perovskite nanocrystals having excellent photosensitive characteristics offer the possibility to achieve next generation optoelectronic devices with superior functionalities. This has been demonstrated through giant photo-amplification in highly stable α-$CsPbI_3$ NCs on layered WS_2 mixed-dimensional heterostructures photo-FET with asymmetric contacts. Utilizing the superior luminescence properties and high colour purity of inorganic perovskite nanocrystals, we reported the fabrication of colour-saturated $CsPbBr_{3-x}I_x$ (x=0-3)/ZnO heterojunctions based white light emitting diodes on a flexible platform. We shall also discuss the doping-induced transition from positive to negative photo-conductance effect in perovskite nanocrystals, expanding their potential for both excitatory and inhibitory optical synapse applications. The optical responses of perovskite nanocrystals provide an opportunity towards developing low power brain-like cognitive systems. Our results highlight the potential of 2D and perovskite hybrid heterostructures for emerging optoelectronic and neuromorphic devices, paving the way for on-chip and energy-efficient computing hardware systems.

Speaker's Profile

Prof. Samit K. Ray is a Chair Professor in the Department of Physics, IIT Kharagpur. He has previously served as the Director S. N. Bose National Centre for Basic Sciences, Kolkata, Dean (Post-graduate & Research Studies) and Head, Physics at IIT Kharagpur. His research interests are in the area of semiconductor nanostructures, quantum technology, and nanophotonic devices. He is an elected fellow of the Indian Academy of Sciences, National Academy of Sciences India, Indian National Academy of Engineering, and is the recipient of INSA Young Scientist Award, UGC Homi Bhabha Award, MRSI Superconductivity & Materials Science Senior Award etc.

Accelerated material discovery: Integrating AI/ML and molecular simulations

Jayant K Singh

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Artificial intelligence (AI) and machine learning are transforming computational materials discovery, opening new pathways for designing materials for gas separation, CO_2 capture, and conversion. From single-atom catalysts and transition metal carbides to MXenes and advanced membranes, AI-driven insights are accelerating progress at the intersection of energy transition and digital innovation.

This talk will highlight proof-of-concept examples of AI in materials discovery. I will first discuss how AI enables the design of 2D crystalline materials—such as MXenes and single-atom catalysts—for hydrogen generation and CO_2 capture. I will then address the challenges of extending these methods to 3D crystalline materials for gas separation and outline strategies to overcome them. Finally, I will introduce the concept of inverse design for discovering novel materials.

Speaker's Profile

Prof. Jayant K. Singh is the Om Prakash Gautam Chair Professor in the Department of Chemical Engineering at IIT Kanpur. He earned his B.Tech. from IIT Kanpur and his M.S. and Ph.D. from SUNY Buffalo, USA. Founder of Prescience Insilico, he has authored over 200 papers and holds seven patents. A recipient of the INAE-SERB Abdul Kalam Technology Innovation National Fellowship, NASI-Reliance Platinum Award, and SERB STAR Award, he is an elected fellow of all four national academies of India. He currently serves as Associate Editor of Chemical Engineering Communications and on advisory boards of multiple ACS journals.

INSA New Fellow Lecture

Complex system approach to investigate and mitigate thermoacoustic instability in turbulent combustors

R.I. Sujith

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Thermoacoustic instability is a catastrophic phenomenon where ruinously large amplitude oscillations of sound are established in jet engines and rockets. Such large-amplitude sound emerges as a result of the feedback between the combustion processes and sound waves in the combustor. Traditionally, a linear framework has been used to study thermoacoustic instability. In contrast, we view thermoacoustic system in a turbulent combustor as a complex system where several nonlinear feedback processes are involved, resulting in the emergence of a variety of intriguing dynamical states. We discuss recent discoveries including different types of transitions leading to thermoacoustic instability. Further, we discuss how our discoveries based on complex system theory are translated to technologies for prognosis and mitigation.

Speaker's Profile

Sujith received his B. Tech from IIT Madras and M. S. (1990) & Ph. D. (1994), from the Georgia Institute of Technology. He is currently an Institute Professor and D. Srinivasan Chair Professor at IITM. He was the founding Editor-in-Chief of the International Journal of Spray and Combustion Dynamics. He is an International Member of the US National Academy of Engineering, a Distinguished Fellow of the International Institute of Acoustics and Vibration and a fellow of the Combustion Institute, INAE, IASc and Ambassador of TU Munich. Sujith's research interests are in the areas of thermoacoustic instability and complex systems theory.

INSA Associate Fellow Lecture

From Earth to Mars: Pioneering Metal-Carbon Dioxide (Metal-CO2) Battery Solutions for a Greener Tomorrow

Chandra Shekhar Sharma

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As climate change intensifies, energy solutions for Earth have become crucial towards a sustainable future. Metal-carbon dioxide (CO_2) batteries offer a transformative approach, converting CO_2 into usable energy while addressing carbon management and reducing emissions. Beyond Earth, these batteries hold significant potential for Mars, where CO_2 is abundant (95 %) providing essential power for future colonies, supporting habitats and life support systems. By harnessing the in-situ resources of Mars, metal-CO_2 batteries could enable sustainable living on the Red Planet. However, its practical implementation faces challenges, including low cyclability, high overpotentials, and poor reversibility due to the thermodynamic stability of discharge products like Li_2CO_3 and amorphous carbon. Our work addresses these challenges by developing unique catalysts including carbon, transition metals, composite nanoparticles. These catalysts enhance the CO_2 reduction and therefore the cyclability of the system. Their bifunctional catalytic behavior helps reduce the activation energy required for the decomposition of the Li_2CO_3 and amorphous carbon, resulting in enhanced reversibility. Benefitting from this, we were able to achieve a cycle life of ~200 cycles at the current density of 500 mA g^{-1} for a limited capacity of 500 mAh g^{-1} along with an operational time exceeding 600 hours. Additionally, we explored translating the system from lithium to the more abundant sodium and potassium metals, paving the way for future sustainable energy solutions.

Speaker's Profile

Prof. Chandra Shekhar Sharma earned his Ph.D. from IIT Kanpur in 2010 and has been with IIT Hyderabad since then, where he currently serves as the Head of the Department of Chemical Engineering. He has also served as Dean (Sponsored Research & Consultancy) at the institute. A recipient of the prestigious Swarna Jayanti Fellowship and an Associate Fellow of the Indian National Science Academy (INSA), Prof. Sharma has authored over 170 research publications and holds several granted patents. He has supervised 19 Ph.D. scholars in diverse areas such as energy storage systems, gas sensors, and drug delivery. His research group is actively engaged in developing advanced battery chemistries—including metal-CO_2, metal-sulfur, and dual-carbon systems—along with nature-inspired functional surfaces towards an eco-friendly, sustainable future.

INSA Young Associate Lecture

CdS Photocatalysts for Visible-Light Hydrogen Evolution: Challenges, Strategies and Future Prospects

D. Amaranatha Reddy

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Hydrogen (H_2) is widely recognized as a clean and sustainable energy carrier for future carbon-neutral societies. Among various H_2 production approaches, photocatalytic water splitting driven by solar energy is highly attractive due to its low cost, environmental friendliness, and abundant sunlight. Cadmium sulfide (CdS) is one of the most promising visible-light-responsive photocatalysts because of its suitable bandgap (~2.4 eV), strong absorption in the visible region, and favourable conduction band position for proton reduction. However, pristine CdS still faces several major challenges, including photo-corrosion, fast electron–hole recombination, and limited surface active sites, which restrict its practical hydrogen evolution efficiency and stability. To overcome these drawbacks, significant research efforts have focused on designing heterojunctions, co-catalyst loading, defect engineering, morphology control, and surface passivation strategies. Coupling CdS with materials such as MoS_2, g-C_3N_4, graphene derivatives, nickel phosphides (Ni_2P), or noble metals can effectively enhance charge separation and improve redox kinetics. Similarly, introducing oxygen/sulfur vacancies and synthesizing nanostructures including nanorods, quantum dots, and hollow spheres has shown remarkable improvement in light harvesting and catalytic performance.

In this talk, we will highlight the recent progress of CdS-based photocatalyst systems for hydrogen fuel production, discuss structure–property relationships and charge transfer mechanisms, and summarize current challenges and future research directions toward scalable, stable, and non-sacrificial system development.

Speaker's Profile

Dr. D. Amaranatha Reddy is an Associate Professor in the Department of Sciences (Physics) at IIITDM Kurnool, Andhra Pradesh. He received his PhD in 2013 from Sri Venkateswara University, Tirupati, and worked as a researcher at Yonsei University and Pusan National University, South Korea, from 2013–2020. His research interests include nanoscale materials for solar fuels (hydrogen production), photocatalytic water purification, CO_2 conversion, and energy storage devices such as solar cells, supercapacitors, and batteries. He has published 130 research papers and currently leads seven funded research projects worth ₹1.7 crore from agencies like SERB, DRDO, APSCHE, UGC-DAE, etc.

Nanostructured Pathways for Sustainable Energy Future

Chirodeep Bakli

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Nanoscale innovations are central to the transition toward a sustainable future, offering enhancements in the efficiency, durability, and adaptability of energy systems. These innovations emerge from an intricate interplay of interfacial physics, molecular transport and energy conversion processes across multiple scales. A combination of experiments, molecular simulations, and data-driven analysis provides a research pathway to establish design principles for controlling wettability, entropy, and heat flow dynamics at the nanoscale. At the fluid-solid interface, wettability-modulated transport, coupled with enthalpic-entropic decomposition analyses, reveals the complex relationship between nanoscale ordering, resultant fluid transport, and energy dissipation. These insights play a vital role in numerous applications, ranging from desalination and oil-water separation to moisture capture and nanoscale transport, where interfacial forces dictate transport and selectivity. These fundamental molecular insights converge to inform the design of nanostructured materials and interfaces for sustainable energy systems, ultimately leading to real, functional systems. This interfacial control transitions into the applied domain of sustainable energy materials, particularly engineered substrates for enhanced transport, low-cost filtration/separation and thermal regulation via passive cooling. These applications, spanning confined nanofluidic channels to macroscale thermal management systems, underscore that molecular-level control of interfacial phenomena can effectively translate into enhanced macroscale energy efficiency. The integration of radiative and evaporative cooling strategies, photovoltaic performance enhancement, and selective separation processes establishes a unified framework that integrates material design with thermodynamics and molecular insights. Collectively, these developments advance the foundation for sustainable, adaptive, and energy-resilient technologies.

Speaker's Profile

Dr. Chirodeep Bakli is an Associate Professor in the School of Energy Science and Engineering at IIT Kharagpur. He has published over 60 papers in leading journals, including Physical Review Letters, Nano Letters, Nanoscale, and Physics of Fluids. His research integrates micro/nanoscale fluid mechanics, interfacial transport, and energy conversion to advance thermal management, energy harvesting, and fluidic diagnostics. Renowned for his work on wettability, electrokinetic flows, and smart surface design, he bridges molecular-scale insights with sustainable energy applications. A senior IEEE member and recipient of the Faculty Excellence Award, he serves on editorial boards and mentors interdisciplinary teams.

INSA Young Associate Lecture

Towards Designing Efficient, Adoptable and Interpretable Large Language Models

Tanmay Chakraborty

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Despite the superior performance demonstrated by Large Language Models across numerous applications involving natural languages, their high computational cost, energy consumption, and limited accessibility underscore the need for efficient, interpretable, and adaptable language models (LMs). This talk highlights methods to develop economical and interpretable LMs that rival their larger counterparts in performance without significant computational requirements. Our research emphasizes three key dimensions: economical resource usage, adaptability to diverse and low-resource tasks, and enhanced interpretability. Techniques like competitive knowledge distillation, leveraging student-teacher dynamics, and activation sparsity in manifold-preserving transformers demonstrate significant efficiency gains without compromising performance. We formulate novel decomposer components for LMs for modularizing problem decomposition and solution generation, allowing smaller models to excel in complex reasoning tasks. We also propose innovative prompt construction and alignment strategies that boost in-context knowledge adaptation in low-resource settings for SLMs. Our findings demonstrate that small LMs can achieve scalability, interpretability, and adaptability, paving the way for broader and sustainable AI accessibility.

Speaker's Profile

Tanmoy Chakraborty is a Rajiv Khemani Young Faculty Chair Professor in AI and an Associate Professor in the Dept. of Electrical Engineering and the School of AI at IIT Delhi. His research primarily focuses on building economical, adaptable and interpretable language models for social good. He served as the DAAD visiting professor at MPI Saarbrucken, PECFAR visiting professor at TU Munich and Humboldt visiting professor at TU Darmstadt. Tanmoy has received numerous recognitions, including the Indian National Academic of Science Young Associate, Ramanujan Fellowship, ACL '23 Outstanding Paper Award, IJCAI'23 AI for Social Good Award, and several faculty awards from industries like Microsoft, Google, LinkedIn, JP Morgan, and Adobe. He has authored two textbooks -- "Social Network Analysis" and "Introduction to Large Language Models". Tanmoy earned his PhD from IIT Kharagpur in 2015 as a Google PhD Scholar.

INSA Young Associate Lecture

Real-Time Hybrid Simulation for Dynamic Response Evaluation of Complex Engineering Systems

Mohit Verma

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Experiments are fundamental to validating scientific theories and hypotheses, providing insights into the intricate phenomena observed in nature. In structural engineering, dynamic behaviour is often studied using quasi-static, pseudodynamic and shake table testing methods. While these methods are widely used, they each have notable limitations. Real-Time Hybrid Simulation (RTHS) is an innovative experimental technique that overcomes the challenges of classical techniques. By combining the physical testing of selected structural components with numerical simulation of the remaining system, RTHS provides a more accurate and economical means of studying complex dynamic behaviour. This approach enables researchers to focus on the critical or poorly understood components of a structure while leveraging computational models for the rest, offering a comprehensive understanding of system dynamics. To enhance the stability and practical implementation of RTHS, a novel impedance matching approach was developed. This method simplifies control design and improves the robustness of real-time coupling between physical and numerical substructures. The developed RTHS framework has been successfully applied to validate vibration control strategies for wind turbines under dynamic loading. It has also been extended to evaluate the performance of elastomeric isolation systems subjected to combined thermal and seismic effects, advancing the experimental investigation of multi-hazard scenarios. These efforts have significantly broadened the applicability of RTHS across diverse engineering domains establishing it as a powerful tool for performance-based design and parametric studies.

Speaker's Profile

Dr. Mohit Verma is currently a Principal Scientist at the Advanced Seismic Testing and Research Laboratory, CSIR-SERC. His research interests include dynamic testing methods, control design for hybrid testing, and active vibration control of structures. He is a recipient of the prestigious Fulbright–Nehru Doctoral and Professional Research Fellowship and the IEI Young Engineer Award in the Civil Engineering Division. Dr. Verma conducted his postdoctoral research at the Precision Mechatronics Laboratory, Université libre de Bruxelles (ULB), Belgium, and at the University at Buffalo, New York, USA.

Sectional Committee VIII

(Biomolecular, Structural Biology and Drug Discovery)

Chair
Dr. Rajendra Prasad Roy, FNA

RP Roy works in the area of protein science and engineering, and has authored several research papers and patents. Dr Roy is a recipient of the National Bioscience Award for Career Development and JC Bose National Fellowship. He is an elected Fellow of all the three major Science Academies of India.
Dr Roy holds a PhD degree from the Indian Institute of Science Bangalore, and is currently the Dean of the Regional Centre for Biotechnology, Faridabad.

From Protein Structures to Medicinal Plants: A smooth continuum

R. Sowdhamini

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Our laboratory has been interested in relationships amongst protein domains where evolutionary divergences may be large, but there are strong similarities in the overall shape and biological function. We proposed structural motifs as constraints to drive computational searches in sequence space. We next built phylogenetic trees to describe these evolutionary variations. This helped us to ask various questions like – is there a common evolutionary ancestor for protein domains that cluster together? Can we extrapolate common biological function whenever protein domains co-cluster? Where do functionally important residues reside? In the process, we chose to study medicinal plants where abundant information is present on evolutionary divergence of enzymatic domains. We chose plants like Tulsi to perform genome assembly and I will share our experiences. Finally, I will also present our more recent study of transcriptome of Aparajitha or Sankapushpi where different biosynthetic enzymes and their tissue localisations could be analysed.

Speaker's Profile

Sowdhamini is a Senior Professor in National Centre for Biological Sciences since 1998. She received her basic degree and Masters in Chemistry. She worked on fold prediction and protein domains during her postdoctoral tenure in Prof Tom Blundell's laboratory in University of Cambridge. Broad research interests in Dr. Sowdhamini's laboratory in NCBS have been in the analysis of protein structural similarities and distant relationships amongst proteins. Sowdhamini was a Wellcome Trust Senior Research Fellow and DBT career fellow. She is a Fellow of Indian National Science Association and Indian Academy of Sciences. She holds a JC Bose Fellowship.

Molecular interplay between FG-Nup98 and Tau through phase separation and co-condensation in Alzheimer's Disease

Timir Tripathi

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Aberrant aggregation of the microtubule-associated protein tau is a defining feature of several neurodegenerative diseases. Recent evidence indicates that monomeric tau interacts with the FG-repeat domain of Nup98, a component of the nuclear pore complex, thereby compromising nuclear membrane integrity and disrupting nucleocytoplasmic transport. These observations suggest that tau–FG-Nup98 interactions precede tau aggregation, yet whether and how these proteins undergo liquid–liquid phase separation (LLPS) prior to oligomerization remains unknown. Here, we integrate in vitro assays, microscopy analyses, and multiscale simulations to elucidate the molecular basis of tau–FG-Nup98 coassembly. Droplet assays, fluorescence recovery after photobleaching, and high-resolution microscopy reveal that tau and FG-Nup98 form heterotypic condensates whose material properties and architectures depend on stoichiometry. These condensates range from homogeneously mixed droplets to nested assemblies with distinct internal organization. Molecular docking and atomistic simulations identify intrinsically disordered interface regions that stabilize co-condensates through a dynamic network of weak, multivalent interactions. These findings establish a mechanistic framework connecting tau LLPS with impaired nucleocytoplasmic transport and suggest that modulating FG-Nup98 phase behaviour could mitigate tau-mediated neurodegeneration.

Speaker's Profile

Prof. Timir Tripathi, Professor of Molecular Biology at NEHU, Shillong, earned his Ph.D. from JNU, New Delhi, while working at CDRI, Lucknow. He previously served as the Regional Director of IGNOU, Kohima, Nagaland. His research focuses on protein-substrate interactions, conformational dynamics, intrinsically disordered proteins in neurodegenerative diseases, and drug-target proteins from Fasciola gigantica. With 150+ publications and 9 books, he serves as Senior Editor of Critical Insights in Biophysics, Editor of the International Journal of Biological Macromolecules (Elsevier), Associate Editor of PLOS Neglected Tropical Diseases, Advisory Board Member of FEBS Letters, and is on the editorial boards of several other leading international journals.

Indian Breast Cancer Genome Atlas: Predicts Cancer Recurrence in Indian patients

Shantanu Chowdhury

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The CSIR supported multi-centre program is making genomic profiles ~1000 breast cancer patient tumors (and matched normal tissue), with follow-up to characterize potential genomic signature(s) associated with response to therapy. Data from the study comprise whole genome sequencing at relatively high depth, transcriptome and epigenome sequencing. Overall the program seeks to not only create India-specific cancer genomic resources, but also aid in identifying actionable molecular signatures of clinical significance. In about 3.5 years, the program has built a network of more than 12 primary hospitals across India, and profiled 800+ breast tumors along with clinical follow up. Interesting trends in molecular attributes of Indian breast cancers are emerging that promise early prediction of potential recurrence.

Speaker's Profile

Shantanu Chowdhury is a professor at the CSIR-Institute of Genomics and Integrative Biology in Delhi. His research interests include understanding mechanisms behind telomerase control and telomere function. Fundamental work from his group on how non-duplex DNA structures impact our understanding of biological mechanisms are widely followed. He currently leads a consortium of more than 100 doctors, data scientists and biologists for a program that is constructing the first-ever Genome Atlas of Indian Breast Cancers. In 2012, Shantanu received the Shanti Swarup Bhatnagar Award in Biological Sciences. He is Fellow of the Indian Academies and former Senior Fellow of the DBT / Wellcome Trust India Alliance.

INSA New Fellow Lecture

Understanding the role of PARK7/DJ-1 Family Proteins in Parkinson Disease Progression.

Patrick D'Silva

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Parkinson's disease (PD) is among the most prevalent neurodegenerative disorders, and its progression is hallmarked by elevated metabolic stress with the accumulation of toxic reactive carbonyl species (RCS) generated in various biochemical pathways, particularly Methylglyoxal (MG) and Glyoxal (GO). Both MG and GO extensively modify and damage cellular macromolecules, causing genetic mutations, DNA breaks, protein aggregation, and organelle dysfunction. Emerging research findings suggest that human DJ-1/*PARK7*, a genetic determinant of PD, may regulate diverse stress conditions and have a protective effect on mitochondrial integrity. However, the molecular insights into how DJ-1 regulates mitochondrial health in PD are still enigmatic.

To investigate this, we utilized *Saccharomyces cerevisiae* as a model organism, which contains four DJ-1 homologs that share similar properties with human DJ-1. Our study highlights that yeast DJ-1 orthologs function as novel enzymes involved in the preferential scavenging of glyoxal and methylglyoxal, toxic metabolites, and genotoxic agents. Their collective loss stimulates chronic glycation of the proteome and nucleic acids, leading to a spectrum of genetic mutations in both nuclear and mitochondrial genomes. In addition, RNA glycation significantly lowered mRNA translational efficiency in the absence of DJ-1 paralogs. Moreover, the DJ-1 paralogs efficiently repair severely glycated macromolecules derived from carbonyl modifications. Under RCS stress conditions, the DJ-1 paralogs redistribute into mitochondria and attenuate the glycation of mitochondrial proteins and mtDNA. They also preserve functional mitochondria and protect the integrity of the genome. Our research findings provide an early lead in understanding how mutations in DJ-1 paralogs are involved in the PD-progression.

Speaker's Profile

Prof. PATRICK D'SILVA Completed Ph.D. from the Department of Biotechnology, IIT-Mumbai (2000), and postdoctoral studies at the University of Wisconsin-Madison, Biochemistry department. Currently Professor at department of Biochemistry, Indian Institute of Science, Bangalore, India. mportant Awards/Recognitions: Fellow of all 3 academies (NASI, IAS, INSA), Swarnajayanthi fellow, Sir. C.V. Raman Karnataka State Science award, Life Sciences Karnataka, State, CDRI-award for Excellence in Drug Research under Biological Sciences, Lady Tata Memorial Trust-award, Wellcome Trust Senior fellow, American Heart Association foundation fellow, Birla Science award, National Bioscience award from DBT. He has authored over 50 publications (Nature Communications, Angewandte Chemie, JACS, eLife).

INSA New Fellow Lecture

Decoding Disease: How Trapped Topoisomerase-DNA Breaks Lead to Genomic Instability

Benu Brata Das

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DNA Topoisomerase 1 (Top1) is a vital enzyme that maintains genomic integrity by resolving DNA supercoiling during replication and transcription. However, Top1 can become cytotoxic when it forms stable cleavage complexes (Top1cc) on DNA, especially in response to anticancer drugs such as camptothecin (CPT) and its clinically approved derivatives, which are used to treat solid tumors including colon, lung, and ovarian cancers. Cells employ sophisticated DNA repair mechanisms to counteract these toxic lesions. A central component of this repair pathway is Tyrosyl-DNA Phosphodiesterase 1 (TDP1), which removes trapped Top1 from DNA in both nuclear and mitochondrial compartments. The activities of TDP1 and associated repair factors are tightly regulated by post-translational modifications (PTMs), which control their function, localization, and interactions. Our research has uncovered that Cyclin-Dependent Kinase 1 (CDK1), along with Protein Arginine Methyltransferase 5 (PRMT5) and Poly(ADP-ribose) Polymerase 1 (PARP1), plays a critical role in modulating the DNA damage response to Top1cc. Together, these regulators orchestrate a finely tuned network essential for effective repair of Top1-induced DNA breaks and maintenance of genome stability, offering promising targets for cancer therapy.

Speaker's Profile

Prof. Benu Brata Das is a Senior Professor at the School of Biological Sciences, Indian Association for the Cultivation of Science (IACS), Kolkata. A leading molecular biologist, his research focuses on DNA repair, mitochondrial genome maintenance, and cancer biology, providing key insights into genome stability and therapeutic innovation. He obtained his Ph.D. (2006) from the Indian Institute of Chemical Biology (IICB) and pursued postdoctoral training (2006–2012) at the National Cancer Institute (NCI), NIH, USA, where he received the NIH Fellows Award for Research Excellence in 2010 and 2011. Prof. Das's pioneering discoveries on DNA topoisomerase I (Top1) and Tyrosyl-DNA phosphodiesterase 1 (TDP1) have identified crucial mechanisms and novel therapeutic targets for cancer and neurodegenerative diseases. His numerous accolades include the DBT-National Bioscience Award (2019), ICMR Award for Basic and Translational Oncology Research (2020), and election as a Fellow of National Academy of Science, India (FNASc) (2020) Indian Academy of Sciences (FASc) (2025). Wellcome Trust India Alliance fellow 2013.

INSA New Fellow Lecture

Novel Mechanisms of AP-Site Recognition and Repair in DNA and mRNA: Insights from *Mycobacterium tuberculosis*

Ravishankar Ramachandran

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Apurinic/apyrimidinic (AP) sites represent critical lesions in both DNA and RNA, posing significant threats to genomic and transcriptomic integrity. In *Mycobacterium tuberculosis* (MTB), efficient recognition and repair of AP sites are vital for bacterial survival under oxidative and UV stress conditions. This talk will explore our seminal findings on the distinct mechanisms governing AP-site repair in DNA and mRNA, focusing on the roles of the class II AP-endonuclease/3'-5' exonuclease (XthA) and the ribosomal protein Rps3 respectively. XthA engages with NAD+-dependent DNA ligase A (LigA) and the ß-Clamp to form a BERosome to counter futile cleavage and ligation cycles in Base Excision Repair, ensuring robust DNA repair. In contrast, Rps3 exhibits a novel AP-endoribonuclease activity, recognizing and cleaving AP sites in mRNA via its conserved 130RR131 motif within the 30S ribosome's mRNA entry tunnel. High-resolution Cryo-EM structures reveal cleaved mRNA products and a hyper-rotated 30S ribosome conformation, facilitating downstream processing by ribosome quality control factors. Knockdown studies in MTB H37Ra further underscore Rps3's protective role against stress-induced mRNA damage. By comparing these mechanisms, this talk will highlight the sophisticated surveillance systems in MTB that safeguard nucleic acid integrity, offering insights into bacterial stress response and potential therapeutic targets and strategies.

Speaker's Profile

Prof. Ravishankar Ramachandran is a Chief Scientist at the CSIR-Central Drug Research Institute (CDRI), Lucknow. He holds a Ph.D. from the Indian Institute of Science, Bangalore and subsequently received the Alexander von Humboldt Fellowship to work with Prof. Robert Huber at Max Planck Institute for Biochemistry, Germany. At CSIR-CDRI, he has made ground-breaking contributions to structural biology and drug discovery, particularly in understanding molecular mechanisms underlying mycobacterial nucleic acid repair. His work on drug-repurposing has led to pioneering Phase III clinical trials of Umifenovir, an antiviral drug for COVID-19, and has advanced therapeutic strategies against tuberculosis, and Chronic myeloid leukemia.