

Uncovering Our Past: Insights from Ancient and Modern Genomics

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For centuries, our understanding of human origins relied on fossils, archaeological discoveries, and comparisons of living species. While these records revealed much about our evolutionary history, they provided only fragments of the story. Today, advances in DNA sequencing, ancient DNA recovery and computational methods development are allowing us to reconstruct the history of our species at fine scales directly from genomes. As a result, the study of human origins has undergone a remarkable transformation—from one relying primarily on fossils and archaeological evidence to one that increasingly integrates diverse sources of data to build a complete picture of human evolution and adaptation.

Ancient genomes have shown that modern humans interbred with Neanderthals, Denisovans, and other now-extinct human groups, overturning the long-held view that these lineages evolved independently. At the same time, increasingly sophisticated computational methods allow researchers to infer population splits, migrations, adaptation, and demographic events from the genomes of both ancient and present-day individuals. These approaches have uncovered migrations that reshaped continents, revealed previously unknown human populations, and identified genetic changes that continue to influence human biology today.

The rapid pace of technological innovation continues to expand what can be learned from genomic data. Improvements in DNA recovery from increasingly challenging samples, large-scale sequencing efforts, machine learning, and statistical modeling are making it possible to investigate questions that were unimaginable only a decade ago. Together, these advances are not only rewriting the history of our species but also providing new insights into the biological changes that make us uniquely human. My talk will explore how integrating ancient and modern genomes is transforming our understanding of human origins, migrations, and evolution.

Background Review Articles

Iasi LM, Chintalapati M, Skov L, Mesa AB, Hajdinjak M, Peter BM, Moorjani P. *Neanderthal ancestry through time: Insights from genomes of ancient and present-day humans*. *Science* 386.6727 (2024): eadq3010.

Moorjani P, Hellenthal G. *Methods for Assessing Population Relationships and History from Genomic Data*. *Annual Review of Genomics and Human Genetics*. 2023;24:305–332.

Paleogenomics and the evolution of human pathogens

Kirsten Bos, Max Planck Institute for Evolutionary Anthropology

A variety of molecules survive in archaeological tissues, including both proteins and DNA. This talk will explore current techniques and discoveries related to the study of ancient DNA from human skeletons, with a focus on bacterial and viral infectious diseases. Ancient pathogen genomes reveal the ancestral forms of modern diseases, which in turn allows us to reconstruct their evolutionary history in terms of where they likely first originated, which forms existed in the past, how they have changed over time, and their relationship to the strains that make us sick today. These concepts will be illustrated with examples of plague, tuberculosis, and syphilis.

Applications of proteomics in human evolution studies

Takumi Tsutaya, Kyushu University

Ancient DNA analysis has developed over the past several decades as a tool that enables the direct tracing of past evolutionary processes of organisms, including humans. Its achievements have been substantial. However, ancient DNA analysis using next-generation sequencing remains a costly approach. Moreover, DNA is prone to degradation during the post-burial period. At present, the temporal limit for obtaining genomic information is approximately 1–2 million years ago under favorable cold conditions such as permafrost, whereas in warm and humid environments with poor preservation conditions, this limit decreases by two to three orders of magnitude.

Ancient protein analysis has recently emerged as a method that partially compensates for these limitations of ancient DNA analysis. Advances in mass spectrometry have enabled palaeoproteomics, the high-throughput and highly sensitive analysis of proteins preserved in archaeological and fossil materials, since the 2010s. Palaeoproteomics can provide information about the past that cannot be obtained through ancient DNA analysis alone. Particularly important are methods for the rapid and cost-effective taxonomic identification of large numbers of bone fragments, and for obtaining genetic and sex-related information from poorly preserved specimens or much older fossils in which ancient DNA does not survive (Figure 1). Using these approaches, fossil materials with significant meanings in human evolution have been identified from among numerous morphologically unidentifiable bone fragments, and molecular phylogeny has been constructed on paleontological specimens dating to ~20 million years ago.

In this presentation, I introduce the current achievements of palaeoproteomics and provide insights into the future developments and applications of palaeoproteomics.

Glossary

- Ancient DNA: Endogenous DNA preserved in archaeological and fossil materials
- Palaeoproteomics: High-throughput and highly sensitive analysis of proteins preserved in archaeological and fossil materials

Background Review Article

Richter K.K. et al., 2022. A primer for ZooMS applications in archaeology. *Proc Natl Acad Sci* 119: e2109323119. <https://doi.org/10.1073/pnas.2109323119>

Warinner C. et al., 2022. Paleoproteomics. *Chem Rev* 122: 13401–13446. <https://doi.org/10.1021/acs.chemrev.1c00703>



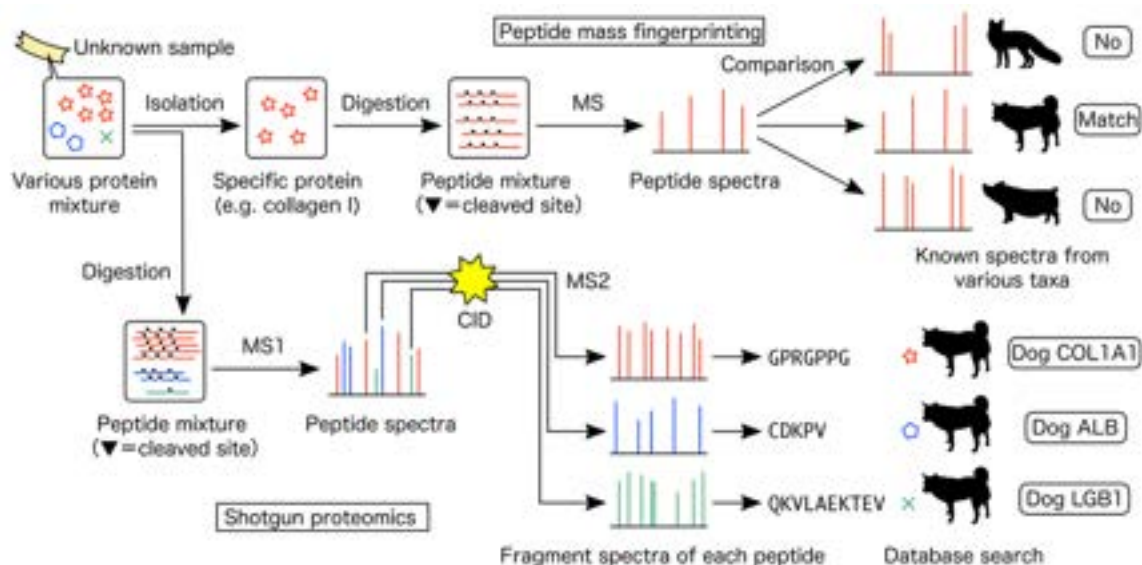


Figure 1. Schematic illustrations of two main analytical frameworks in palaeoproteomics

Robots That Learn to Handle the Physical World: Why Structure Beats Scale

Georgia Chalvatzaki, Technical University of Darmstadt

Modern artificial intelligence (AI) can write text and recognize images at a remarkable level, yet no robot today can reliably tidy an unfamiliar kitchen or assemble a device it has not seen before. The bottleneck is physical interaction. When a robot grasps, pushes, or assembles objects, it must deal with contact: the instant two surfaces touch, forces change abruptly and the smooth mathematics of motion breaks down. The dominant recipe in AI today is to collect ever larger datasets and train ever larger models. For systems that act in the physical world this recipe alone is not enough, because the world supplies far less data than the internet and punishes mistakes immediately. My research asks a different question: what knowledge about the physical world should be built into a learning system from the start? I argue that four kinds of structure are decisive. The symmetry of a robot's body, so that a skill learned with one arm transfers to the other. The mechanics of contact, so that the system reasons correctly about forces and friction. The geometry of scenes and objects, so that perception and planning share one consistent spatial language. And the structure of tasks, so that complex goals break down into reusable steps the robot can recombine. Building these in makes robots learn faster, act more reliably, and transfer skills across tasks and machines. The take-home message is that for machines that act in the world, the right structure, not only more data, is what turns learning into competence. I will close with open problems where other disciplines can help.



Our bimanual mobile robot learning to open and handle everyday furniture and objects.



BODY

CONTACT

SCENE

TASK

Four kinds of physical structure we build into learning: the body's symmetry, the mechanics of contact, the geometry of the scene, and the structure of the task.

Glossary

- Embodied AI. Artificial intelligence placed inside a physical body, such as a robot, that must sense and act in the real world rather than only process data on a screen.
- Manipulation. A robot's ability to physically handle objects, for example grasping, moving, or assembling them.
- Contact mechanics. The physics of what happens when two surfaces touch, where forces can appear and change suddenly. This makes prediction and control unusually hard.
- Symmetry (equivariance). The idea that if a situation is flipped or rotated, the correct response flips or rotates the same way. Exploiting this lets a system reuse what it has learned instead of relearning it.
- World model. An internal predictor a robot uses to imagine what will happen if it takes an action, so that it can plan before it moves.

Further reading

PEARL Lab, Technical University of Darmstadt. <https://www.pearl-lab.com>

ERC Starting Grant SIREN (Structured Interactive Perception and Learning for Holistic Robotic Embodied Intelligence), No. 101163933, 2025-2030.

Whole-Body Mobile Manipulation using Offline Reinforcement Learning on Sub-optimal Controllers, <https://arxiv.org/abs/2604.12509>

IMPACT: An Implicit Active-Set Augmented Lagrangian for Fast Contact-Implicit Trajectory Optimization, <https://arxiv.org/abs/2605.09127>

Semantic-Geometric Task Representations for Bimanual Manipulation from Human Demonstrations to Robot Action Planning, <https://arxiv.org/abs/2601.11460>

Morphologically Symmetric Reinforcement Learning for Ambidextrous Bimanual Manipulation, <https://arxiv.org/abs/2505.05287>

SE(3)-DiffusionFields: Learning Smooth Cost Functions for Joint Grasp and Motion Optimization through Diffusion. <https://arxiv.org/abs/2209.03855>

Quantifying the Real World with Measurement and Design: from Objects to the Senses

Yukie Nagai, University of Tokyo

“Bodies” is not merely arms and legs, but a cycle of sensing the real world, acting upon it, and verifying the results. A robot's senses are realized by measuring physical and chemical quantities, so embodied AI that interacts with objects must measure the world.

Measuring the world as it is, however, remains difficult, and is a bottleneck. A realistic appearance does not guarantee reliable dimensions or material properties. Some objects are especially hard to measure: soft foods, and internal structures hidden from view. Measuring them would let care robots handle foods and enable in-line inspection of products with industrial robots. I introduce two technologies for this purpose: three-dimensional measurement of foods, and robotic X-ray CT, where the robot moves in order to measure and is itself a form of embodied AI.

Relating object structure to human perception lets us design sensations (Fig. 1). We have developed an algorithm for designing food internal structures that realize intended textures^[1], which additive manufacturing can turn into real objects.

Once measured, these objects have known properties with quantified uncertainty, and can serve as training data and benchmarks for robots and as controlled stimuli for studying human perception.

Open challenges include new measurement principles, especially for smell and taste, AI that decides what to measure and how precisely, design methods that account for human senses, and better fabrication technology. If texture can be designed, alternative proteins can become foods that people gladly accept, which would help mitigate food shortages caused by climate change and enrich eating for elderly people. Embodied AI requires not only knowing the world but also verifying it, which demands cross-disciplinary breakthroughs. Let us exchange ideas freely in this diverse community.

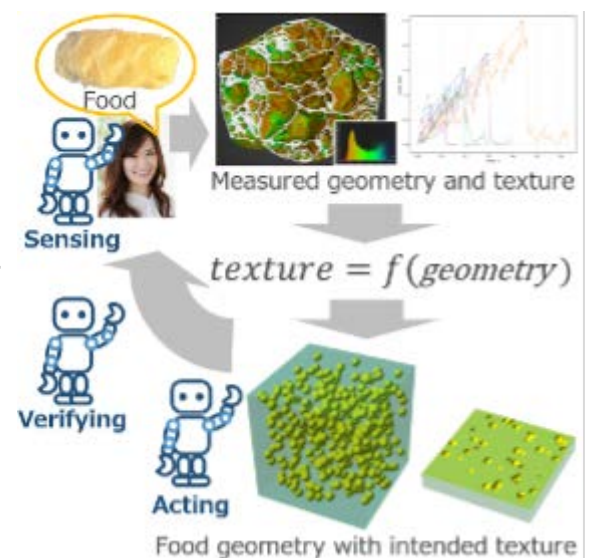


Fig. 1 Realizing embodied AI through a cycle of sensing the real world, acting upon it, and verifying the results.

References

- [1] Hikaru TANAYA and Yukie NAGAI "Investigating the relationship between geometric features of voids and textures in aerated foods", Journal of Advanced Mechanical Design, Systems, and Manufacturing, 2022, 16 (6), p. JAMDSM0062, <https://doi.org/10.1299/jamdsm.2022jamdsm0062>

Language is Discrete, the World is Continuous

Yonatan Bisk, Carnegie Mellon University

Embodied AI has emerged as an umbrella term that targets questions that cut across Robotics, Natural Language Processing (NLP), Computer Vision, and Machine Learning. While the idea is simple, “What if AI had a body”, the details are anything but. Every design decision influences representations and where the challenges lie: What is a body? What are assumed interfaces? Where does knowledge come from? and so forth. My personal background started in NLP and moved to robotics and this still influences how I run my lab and how I view the field.

Most of the field assumes that human interaction comes via language, often tokens or written words, but every action eventually translates into a real valued control signal (e.g. a direction vector, a gripper pose, or an actuator's force). The result is a struggle as to where to put this knowledge-to-control interface: how to move towards more abstract or complex reasoning without losing access to the world. I will present a landscape of current approaches (e.g. via Large Language Models (LLMs), Vision Language Models (VLMs), and Vision Language Action models (VLAs)) and where they sit with respect to the history of the field. This will include recent results from my lab on where there is strength in sharing knowledge across modalities and where there are open challenges.

Background Review Articles

Toward General-Purpose Robots via Foundation Models: A Survey and Meta-Analysis (2023).
<https://robotics-fm-survey.github.io/>

Bridging Language and Action: A Survey of Language-Conditioned Robot Manipulation, *International Journal of Robotics Research* (2026). <https://arxiv.org/abs/2312.10807>





Glossary of Terms

- Embodied AI: AI systems that perceive and act in the physical world, rather than only processing text or images — the “body” forces some knowledge of physics, noise, potentially humans, etc.
- Token / Tokenization: The unit a language model actually reads — usually a word-fragment, not a whole word (e.g. “happiness” might become “happi” + “ness”) — this is not the same as traditional lemmatization in linguistics. Such chunked representations are now required for images and actions as well.
- Control signal: The literal number(s) sent to a motor or actuator — a joint angle, a force, a velocity vector. Continuous and often in R^3 or R^7 .
- Policy: In robotics/RL: a function that maps “what the robot currently observes” to “what action it should take next.”
- Grounding/ grounded language: Connecting a word or symbol to its actual referent in the physical world — “cup” isn’t grounded until a system can point to, recognize, or pick up the cup, not just use the word correctly in a sentence.
- VLM (Vision-Language Model): A model that takes in both images and text and can reason about their relationship (e.g. answer questions about an image).
- VLA (Vision-Language-Action model): A VLM extended to also output actions/control signals — the model that’s supposed to close the loop from perception through language to physical movement.
- Fine-tuning: Taking an already-trained model and continuing to train it, briefly, on a smaller/more specific dataset — adaptation, not training from scratch.
- Affordance: A property of an object or environment that suggests how it can be acted on — a handle affords grasping, a flat surface affords placing. Originally a psychology/perception term (Gibson), now often used loosely as “abilities” or “uses”.
- Multimodal: Involving more than one type of input or data — e.g. combining vision and language, rather than just one.

Ocean microplastics, their fate, effects, and policy making

Haruka Nakano, Kyushu University

Plastic pollution has emerged as one of the most critical global environmental issues, driven by the rapid increase in plastic production and the continuous release of plastic waste into aquatic environments [1,2]. Plastics fragment into microplastics (<5 mm) and nanoplastics (<1 µm), which have been detected in oceans, rivers, sediments, the atmosphere, polar regions, and living organisms. Their widespread occurrence has raised concerns regarding ecosystem health, food security, and human well-being. Despite significant scientific progress, major challenges remain in understanding their environmental fate, improving analytical methodologies, evaluating ecological impacts, and supporting effective management.

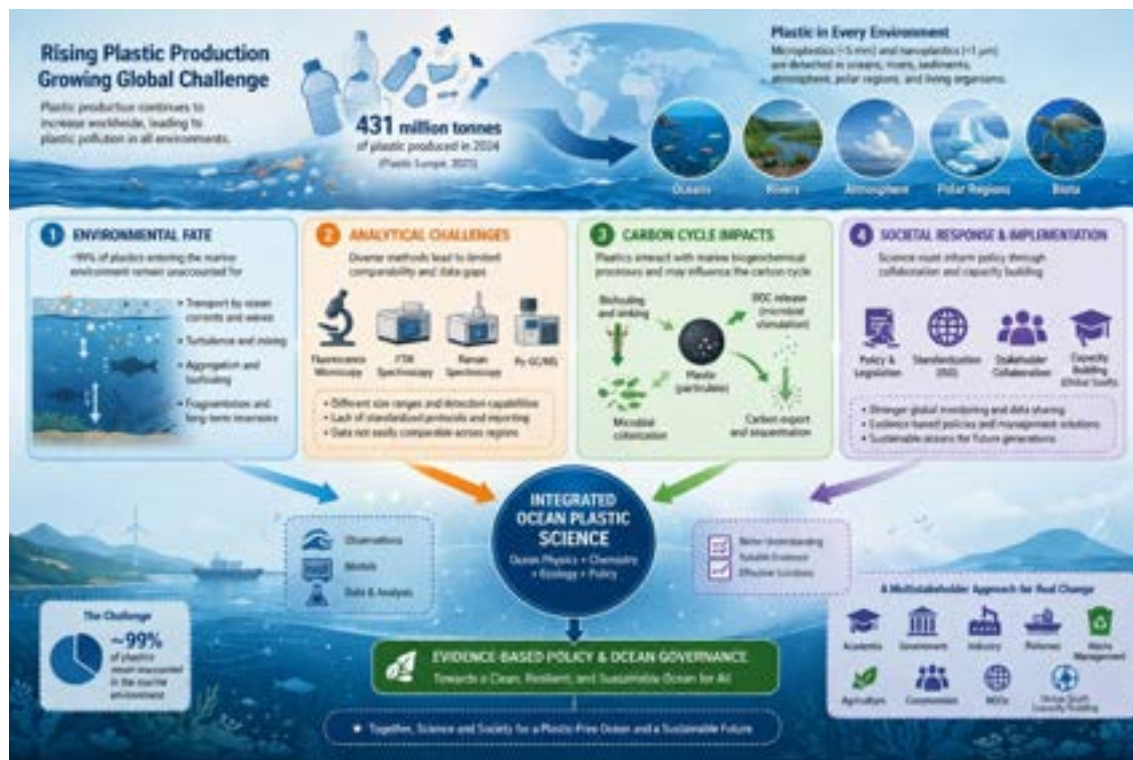
One of the greatest challenges is elucidating the environmental fate of microplastics. Approximately 99% of plastics entering the marine environment remain unaccounted for, reflecting substantial uncertainties in transport, accumulation, and long-term reservoirs. Although particle-tracking models have improved our understanding of large-scale transport, they remain poorly constrained by observational data. Oceanographic processes, including turbulence, vertical mixing, buoyancy, aggregation, and biofouling, strongly influence microplastic distributions, highlighting the need to integrate ocean physics with field observations.

Analytical challenges also limit progress in microplastic research. Diverse sampling strategies and analytical techniques, such as fluorescence microscopy, Fourier transform infrared (FTIR), Raman spectroscopy, and pyrolysis-gas chromatography/mass spectrometry (Py-GC/MS), generate datasets that are often difficult to compare because they target different particle-size ranges and reporting metrics. Internationally harmonized analytical protocols and standardization efforts, including ISO activities, are therefore essential for improving data comparability and supporting global monitoring and evidence-based policymaking.

Recent studies further suggest that plastics may influence marine biogeochemical cycles through biofouling-induced sinking, the release of dissolved organic carbon, and microbial interactions. These findings indicate that plastic pollution should be considered not only as a waste management issue but also as a component of marine ecosystem functioning and the global carbon cycle.

Addressing these challenges requires interdisciplinary collaboration among oceanographers, analytical scientists, ecologists, policymakers, industries, and international organizations. Such collaboration will improve our understanding of microplastic dynamics and provide robust scientific evidence for effective environmental management and sustainable ocean governance.





References

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- [2] Jambeck et al., (2015). Plastic waste inputs from land into the ocean. Science. 347(6223). pp. 768-771.

Glossary

- ISO: International Organization for Standardization
- Microplastics: Particles with diameters less than 5 mm, defined as the primary, meaning manufactured, and the secondary, meaning pieces broken down from large plastic items.

The Fluid Mechanics of Ocean Microplastics

Michelle DiBenedetto, Princeton University

Microplastic pollution is ubiquitous in the ocean. Assessing and mitigating this threat to ecosystems and human health requires accurate prediction of microplastic fate and transport in the marine environment. At global scales, progress has been made by combining ocean circulation models with surface observations, characterizing large-scale patterns such as the accumulation of floating plastic in gyres. However, these models often fall short at smaller scales: processes such as vertical transport, horizontal dispersion, and fluxes across ocean boundaries, e.g., at beaches and the air-sea interface, remain poorly constrained, yet they control how plastic moves between the ocean surface, the water column, coastlines, and the atmosphere.

In this talk, I will describe the fluid mechanics governing these smaller-scale processes. Microplastics differ from other common environmental particles such as sediment and bubbles: they are often near-neutrally buoyant in seawater, of finite size, and irregularly shaped. These properties, combined with the multiscale forcing from waves and turbulence near the ocean surface where microplastics tend to reside, place them in a regime of particle-laden flows that is poorly characterized. Using results from theory, laboratory experiments, and field measurements, I will show how surface waves, turbulence, and particle properties affect their transport, connecting these results to how they can inform both measurements and models. I will conclude with open questions in the field, highlighting the need for interdisciplinary research in predicting the fate of plastic in the ocean environment.

Background Review Articles

1. DiBenedetto MH. 2026. The fluid mechanics of ocean microplastics. *Annu. Rev. Fluid Mech.* 58:355–82. <https://doi.org/10.1146/annurev-fluid-120423-012604>
2. van Sebille E, et al. 2020. The physical oceanography of the transport of floating marine debris. *Environ. Res. Lett.* 15:023003. <https://doi.org/10.1088/1748-9326/ab6d7d>

Microplastic pollution in the ocean – a complex challenge

Lisa Roscher, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research

Microplastics have been recorded in environments all over the globe, reaching from terrestrial to marine realms, including the Polar regions and deep-sea sediments. Once in the environment, they can be harmful to organisms throughout the food web, spanning from mechanical damage by sharp-edged fragments to adverse effects on a cellular level. To better understand this pollutant and its fate in the environment, standardized strategies for reliable detection and analysis are crucial. This is an ongoing challenge, complicated by the fact that the term ‘microplastics’ not only covers one specific pollutant type, but rather serves as umbrella term for various synthetic polymers and their blends, showing varying characteristics and behaviours in the environment. Besides the chemical composition, also particle morphologies can vary strongly in environmental samples (Fig. 1). Measured size distributions are typically skewed to smaller size classes (Fig. 2), which can be attributed to fragmentation processes in the environment, e.g. through UV weathering or mechanical impact. With a decrease in size, the ecotoxicological impact increases, allowing particles to bypass biological barriers. Overall, the problem of microplastic pollution can only be tackled with a highly interdisciplinary approach. It requires expertise in several fields reaching from oceanography, biochemistry, ecotoxicology, analytical chemistry, informatics to modelling, to be able to address challenges in monitoring and open questions regarding the impact on organisms and ecosystems. The obtained data can build the foundation for political mitigation and societal awareness, ideally aiming at preventing the transportation to the environment in the first place.

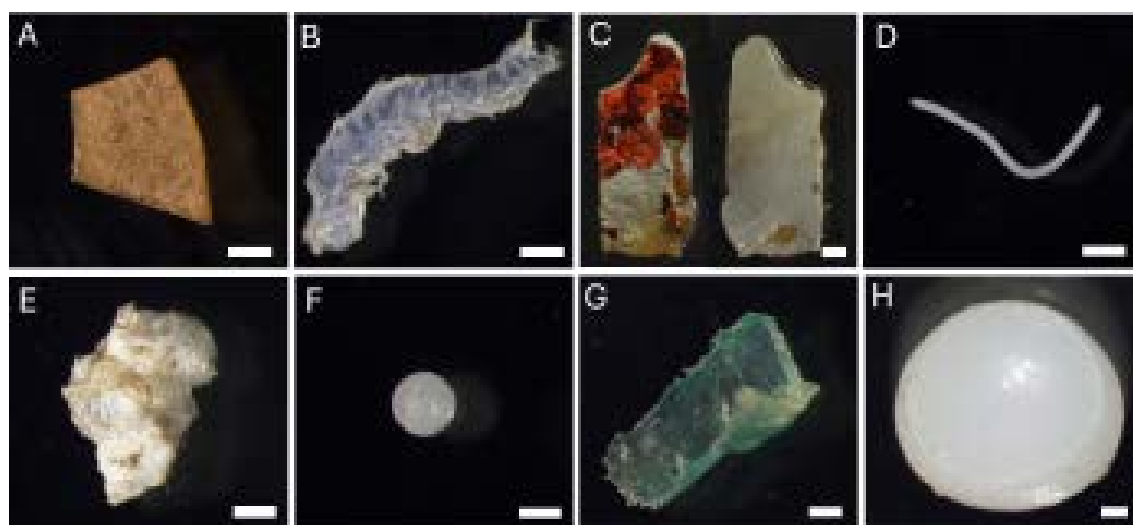


Fig. 1: Different morphologies of microplastics (>500 μm) detected in surface water samples of the Weser North Sea transitional system. A: polyethylene fragment; B: polyethylene fragment; C: varnish fragment; D: polypropylene filament; E: polystyrene foam; F: polyethylene sphere; G: polyethylene film; H: polyethylene pellet. Scale bar: 500 μm . Modified from ^[1].

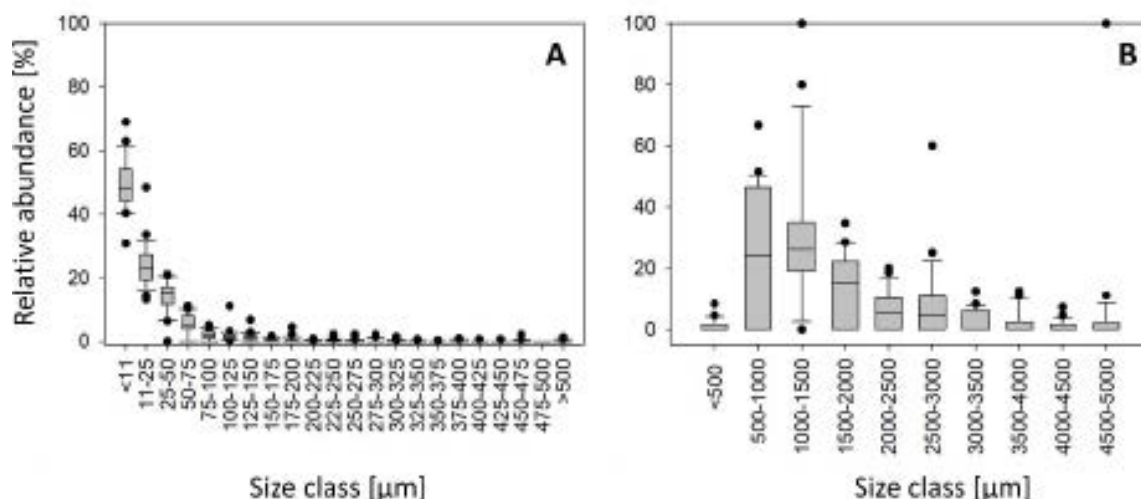


Fig. 2: Size class distributions of microplastics detected in the German Weser North Sea transitional system. In this study, two sample fractions, <500 µm (A) and >500 µm (B), were analysed using different sampling strategies and analytical pipelines. Modified from ^[1].

Glossary

- Microplastics: Commonly defined as synthetic organic pollutants with a size smaller than 5 mm
- FTIR spectroscopy: Fourier Transform Infrared Spectroscopy; spectroscopic method which allows identification based on material-specific absorbance patterns; common technique for the enumeration of microplastic particles and polymer identification.
- Pyrolysis GC/MS: Pyrolysis Gas Chromatography; thermo-analytical method used for material identification; commonly applied for mass quantification of plastic polymers.

Further reading

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Information Is Quantum Mechanical: Quantum Information Science and the Future of Computation

Keisuke Fujii, Kyoto University

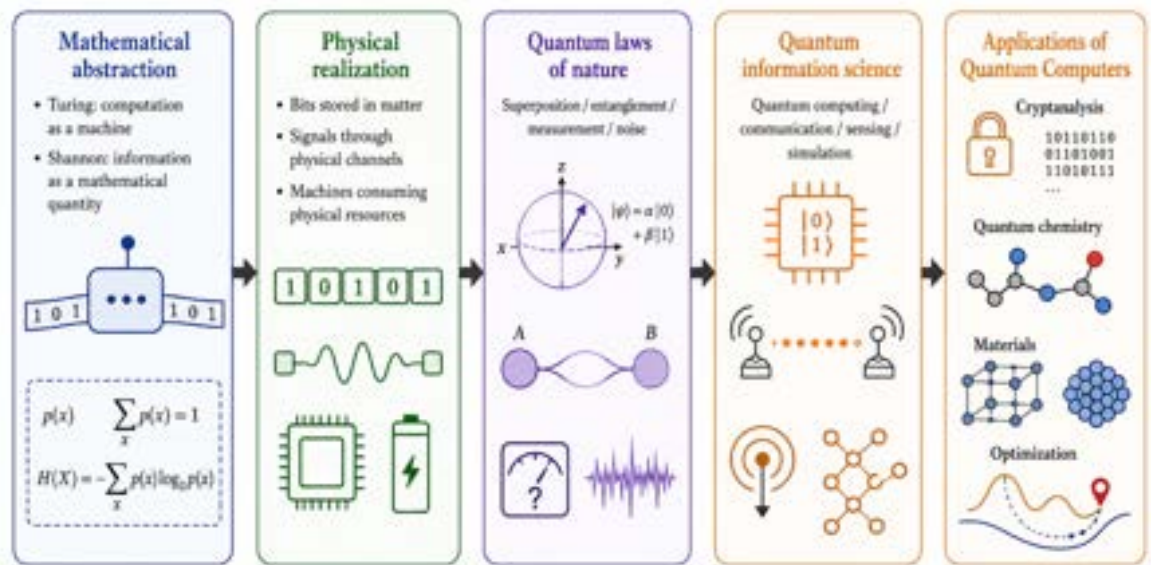
“Information is physical,” as Rolf Landauer famously wrote ^[1]. Modern society is supported by information technologies, from computers and the Internet to artificial intelligence. Their success was enabled by powerful abstractions: Turing idealized computation as the operation of a machine ^[2], and Shannon formulated communication mathematically ^[3]. But is this classical abstraction—the idea that information can be treated independently of its physical carrier—the most general form of information allowed by nature? A bit must be stored in matter, a signal must travel through a physical channel, and computation must be carried out by a physical machine. The ultimate limits of information processing are therefore limits set by physics.

Quantum mechanics is our most fundamental description of nature. It allows forms of information with no classical counterpart, including superposition, a coherent combination of alternatives, and entanglement, unusually strong correlations between systems. Quantum information science asks how these properties change computation, communication, and measurement ^[4,5].

Rather than presenting quantum information science as a set of specialized techniques, this session will introduce it through two broad aspects. The first is the foundation and fascination of quantum information: what it means to regard information itself as something governed by quantum mechanics, and why this changes our view of nature. The second is the impact of quantum computing: what may become possible when quantum information is used as a principle of computation, and which fields—from physics and chemistry to materials science, cryptography, optimization, and artificial intelligence—could be affected by such a change ^[6].

In the age of AI, this question is no longer only philosophical. As AI and data-intensive science expand, computation itself is becoming a scarce physical resource, constrained by hardware, energy, and time. This makes new computing principles—not merely faster classical hardware—increasingly important. Quantum computing offers one of the most compelling routes, especially for problems whose structure is intrinsically quantum, such as molecules, materials, and many-body systems.





References

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- [2] A. M. Turing, "On Computable Numbers, with an Application to the Entscheidungsproblem," *Proceedings of the London Mathematical Society* 42, 230–265 (1936/1937).
- [3] C. E. Shannon, "A Mathematical Theory of Communication," *Bell System Technical Journal* 27, 379–423 and 623–656 (1948).
- [4] C. H. Bennett and D. P. DiVincenzo, "Quantum information and computation," *Nature* 404, 247–255 (2000).
- [5] M. A. Nielsen and I. L. Chuang, *Quantum Computation and Quantum Information*, 10th Anniversary Edition, Cambridge University Press (2010).
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Glossary

- Qubit: The basic unit of quantum information. Unlike a bit, a qubit is described by the rules of quantum mechanics.
- Superposition: A quantum state in which several alternatives are combined coherently, rather than being simply one definite alternative.
- Entanglement: A form of quantum correlation between systems that cannot be explained by ordinary classical correlations.
- Quantum computer: A computer that uses quantum information as the basis of computation. It is not simply a faster classical computer, but a different model of computation based on quantum mechanics.

Background Review Article

- I. H. Deutsch, "Harnessing the Power of the Second Quantum Revolution," *PRX Quantum* 1, 020101 (2020).
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Quantum Sensing in Biology: From Diamond Qubits to Protein Qubits

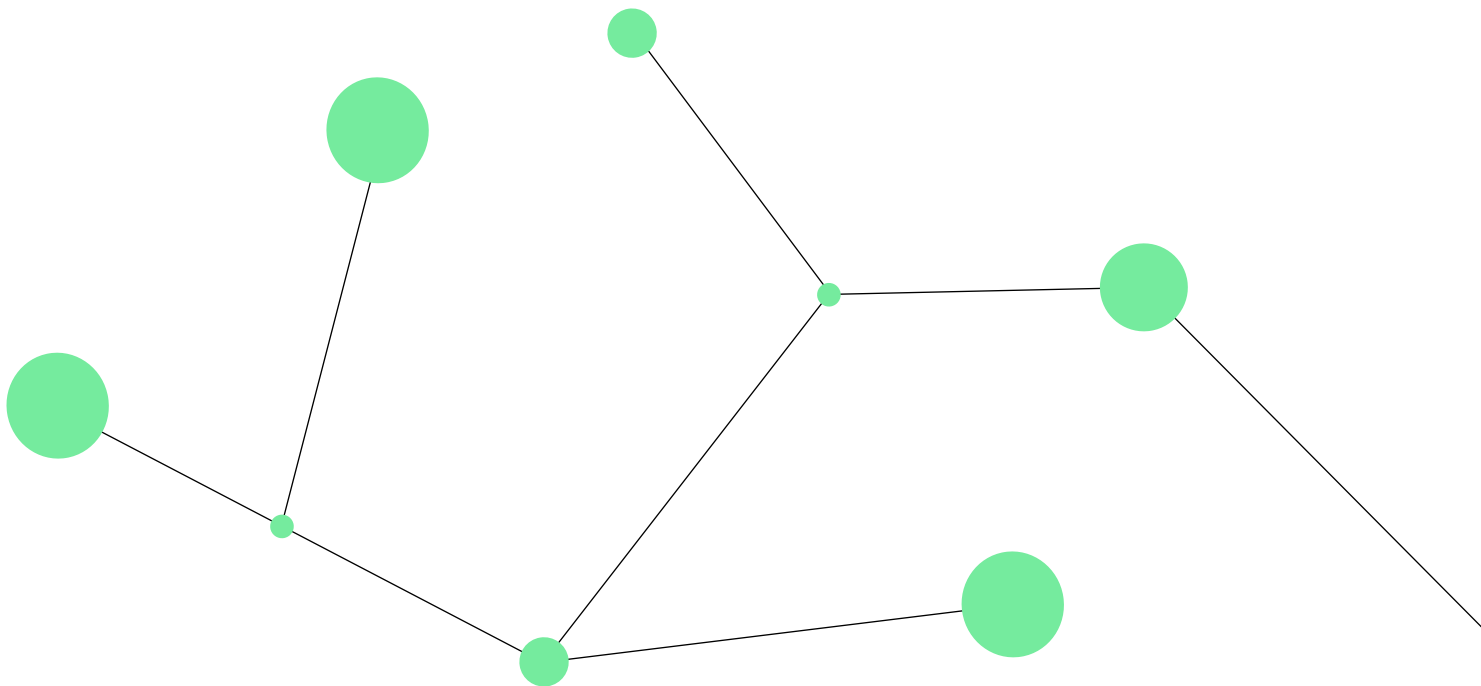
Peter Maurer, The University of Chicago

Quantum sensing provides a powerful framework for measuring magnetic fields, temperature, and chemical processes with exceptional sensitivity and spatial resolution. These capabilities are increasingly relevant to the life sciences, where new tools are needed to probe molecular and cellular processes. Quantum sensors could enable nanoscale magnetic resonance of biomolecules, local measurements of ion and metabolite concentrations, and readout of molecular interactions and conformational changes. However, bringing ultra-sensitive quantum sensors into living systems remains a major challenge: many leading platforms rely on solid-state hosts that are difficult to position with molecular precision, interface with intracellular targets, or engineer using molecular biology tools. This poster highlights our lab's development of a new class of biological qubits based on optically addressable spins in fluorescent proteins. These genetically encodable protein qubits combine molecular-scale dimensions of approximately 3 nm with optical spin readout and coherence approaching that of solid-state defects. By uniting quantum engineering with the programmability of biology, this platform opens new opportunities for targeted, minimally invasive quantum sensing inside cells and for probing biological processes at the molecular scale.

NV magnetometry as the precision sensing tool

Aparajita Singha, TU Dresden

Nitrogen vacancy centers (NV) in diamond are famous for their ability to measure very small magnetic fields across a broad range of temperature, covering both room temperature as well as cryogenic regimes. My research group focusses on utilizing these quantum sensors for non-invasive probing of isolated magnetic molecules on surfaces, which are difficult to access using other complementary techniques. Another aspect of our current research involves two-dimensional mapping of both static and dynamic magnetization profile of synthetic antiferromagnets, as well as nanoscale devices, using scanning probe NV magnetometer. The key idea here is to identify their local nanoscale properties which are often obscured in conventional transport measurements. After introducing the essential concepts of nanoscale quantum sensing and providing a broad overview of the current research scopes in my experimental group, I will also highlight on the current challenges and the opportunities in this vibrant field of research.



Through the Eye of the Storm: Post-Hurricane Migration in Florida's Panhandle

Dontá Council, Federal Reserve Bank of Atlanta (with *Seumalu Elora Raymond*, formerly Georgia Institute of Technology, and *Pearse Haley*, Federal Reserve Bank of Atlanta)

When a major hurricane strikes, some residents leave and never return. But who leaves, where do they go, and do they end up in better or worse neighborhoods than the ones they left behind? These questions matter because a move after a disaster can either open a path to opportunity or deepen existing disadvantage.

This presentation examines migration from Florida's Panhandle after Hurricane Michael, the Category 5 storm that devastated Bay County (home to Panama City) in October 2018. Using an anonymized, individual-level panel drawn from consumer credit records, we tracked where residents lived before the storm and for three years afterward. To separate storm-driven moves from ordinary relocation, we compared Bay County to nearby Escambia County, which is demographically similar but was spared by the storm.

We find that the storm caused about 5.2 percent of Bay County residents to leave over three years, and unlike many disasters, out-migration grew rather than faded each year. On average, movers landed in slightly better neighborhoods, but the averages conceal a widening divide: residents of advantaged neighborhoods moved to even more advantaged places, while residents of disadvantaged neighborhoods moved to areas of deeper deprivation. Credit scores, age, homeownership, and student loan debt were among the strongest predictors of who could move to opportunity. Storm-affected residents also fared worse than comparable movers from the unaffected county, suggesting that recovery policy did not fully offset the storm's effects. The findings point to a role for relocation assistance that helps displaced residents, particularly those with weaker credit, reach neighborhoods of similar or better quality.

Background Review Articles

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Esnard, A. M., and A. Sapat (2014). *Displaced by Disaster: Recovery and Resilience in a Globalizing World*. Routledge. DOI:[10.4324/9780203728291](https://doi.org/10.4324/9780203728291)

From hazard to impact: The need for new practices of anticipation of meteorological events

Thomas Kox, Weizenbaum Institute

Traditionally, weather warnings emphasized the nature and likelihood of meteorological phenomena (e.g., storms, heavy rain), representing a hazard-focused model. However, recent developments have shifted toward impact-based warnings, which communicate the potential consequences of weather events—such as traffic disruptions, infrastructure damage, or public safety risks. This shift aims to make warnings more relevant and actionable, particularly for emergency services and the public, by linking forecasts to realworld impacts. Despite this progress, the transition introduces significant challenges. Impact-based warnings operate in contexts of high uncertainty, especially for rare, highimpact events (e.g., floods, wildfires, heatwaves), where emergency services often lack experience and historical data. This leads to difficulties in interpreting warnings, predicting public and organizational responses, and adapting to changing conditions such as urban development or evolving communication technologies. Purely calculative approaches relying on models and probabilities may be insufficient for managing uncertainty. Instead, new practices of anticipation are needed. Training, simulations, and crisis exercises that create experiential, causal knowledge and help emergency personnel anticipate and respond to complex situations by simulating real-world conditions through physical, sensory, and technical engagement; and scenario planning, storytelling, and strategic foresight that explore plausible, non-probable futures that help organizations prepare for unexpected or unprecedented events, foster collaboration across sectors, and build shared understanding of future risks.

Glossary of Terms

- Anticipation: the process of preparing for and making sense of future events, particularly uncertain or potentially hazardous ones, before they occur.
- Emergency Management: The organized effort of preparing for, responding to, and recovering from emergencies and disasters, to manage the risks and consequences of disasters.
- Impact: The potential consequences or effects of a natural hazard on people, property, infrastructure, and society.
- Natural Hazard: A specific phenomenon or event that has the potential to cause harm. It is characterized by its magnitude and frequency. Examples of hazards include rain, storms, snow, dust storms, tornadoes, heatwaves, floods, blizzards, and wildfires.
- Risk: Not just the danger itself (the hazard), but the complex interplay of that danger with human society, perception, decision-making, and the potential for negative consequences. It is a dynamic concept shaped by knowledge, values, and the need for action to prevent harm.
- Uncertainty: It is not a single, simple concept but is differentiated into several layers, primarily based on the degree of knowledge about an event's occurrence and its consequences.





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Human and Residential (Im-)Mobility Across Disaster Phases in the Era of Climate Change

Kensuke Otsuyama, Kobe University

With the increasing frequency and severity of climate-change-induced natural hazards, advanced visualization technologies and municipal training methodologies have significantly progressed in Japan. Recent frameworks integrating meteorological reanalysis with real-time risk maps successfully visualize localized risks and improve training content realism. However, while institutional preparedness advances, community-level responses demand increasingly diverse pre-evacuation activities. A study utilizing mixed-methods analyses with mobile spatial statistics and workshop narratives reveals that repeated exposure to hazards alters human behavior; vulnerable populations such as the elderly are evacuated first, while other residents prioritize localized mitigation and economic asset protection. These results imply that short-term mobility can be altered by neighborhood characteristics in case of emergency.

On the other hand, in the aftermath of disasters, long-term human displacement introduces further socio-geographical complexities. Post-disaster recovery and relocation processes reveal a stark divergence in mobility, as a household's capacity to move or adapt is deeply rooted in multi-layered socio-economic conditions. While certain demographic segments exhibit high mobility, others remain highly immobile or functionally trapped due to factors such as low income, a lack of insurance, and social disconnection. Consequently, long-distance relocation often diminishes place attachment and destabilizes neighborhood voluntary civic associations due to the outflow of younger generations. To bridge these gaps, targeted interventions are required. Future disaster management and disaster recovery policies should look beyond conventional, uniform approaches; instead, it is essential to incorporate adaptive and inclusive interventions that support localized community communication networks, accommodate diverse pre-evacuation activities, and address the institutional vulnerabilities of structurally trapped populations across both the emergency and long-term recovery phases.

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Glossary

- (Im-)Mobility:【移動と不動】
The spectrum of a person's capability to move, ranging from full freedom of movement to complete inability to relocate due to physical, financial, or social constraints.
- Reanalysis:【再解析】
The systematic reconstruction of past weather and climate data by combining historical observations with modern numerical weather prediction models to create highly accurate, high-resolution historical records.
- Vulnerable Populations:【脆弱性を有する人々】
Groups of people who face higher risks during disasters due to structural disadvantages, such as elderly individuals, low-income households, people with disabilities, or marginalized communities.
- Social Disconnection:【社会的断絶】
The breakdown of community networks, support systems, and interpersonal relationships that often happen when disasters displace neighborhoods and separate families.
- Place Attachment:【地域への愛着】
The emotional, cognitive, and cultural bond that a person develops with their home or neighborhood, which can sometimes make them reluctant to evacuate high risk areas.
- Trapped Populations:【移住できない人々】
Individuals or groups who wish to evacuate a high-risk area but are unable to do so because they lack the financial resources, physical capability, or transportation options.
- Long-distance Relocation:【遠距離移住】
The permanent or semi-permanent migration of disaster survivors to an entirely new region or city, often required when their original community becomes uninhabitable.

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From 3D nanoclusters to single atomic sites: Low-dimensional materials to solve grand challenges in catalysis, the energy transition and beyond

Lars Mohrhusen, Carl von Ossietzky University of Oldenburg

Making and breaking chemical bonds with high selectivity and efficiency is a key process for a sustainable future, ideally leveraging solar light as a renewable energy source.¹ Such catalytic conversions can be realized in a variety of environments surrounding the active atomic site, ranging from complex organic ligands, as seen in enzymes or homogeneous molecular catalysis, to solid or crystalline environments typical of heterogeneous catalysis. In virtually all cases, chemical reactions occur at an individual active site embedded within a matrix of other atoms, which often play a predominant role in controlling reaction pathways and steering selectivity.

Unfortunately, many of these catalytically active materials, such as noble metals (e.g., platinum group metals), are scarce and classified as critical raw materials. Consequently, maximizing dispersion is desired, which is practically achieved by reducing dimensionality to atomically thin single-layer films (2D materials)², small ensembles (2D nanoclusters), or even individual atoms (0D)^{3–5} of the active component.

Beyond increased dispersion, the properties of these active materials can be fundamentally altered and controlled. This allows for the generation of unique electronic states that differ from bulk materials (e.g., the edge states in MoS₂ particles)⁶, the tuning of reactivity via dilute alloying (e.g., dilute alloys of Pt and Pd for selective hydrogenation catalysts)^{7–9}, or the overcoming of fundamental challenges such as scaling relations.¹⁰ Although the concept of single-layer or single-site materials is not entirely new (single oxygen vacancies, for instance, have been utilized in selective oxidation catalysis for decades) the stabilization and characterization of such sites remains a challenge. Understanding their fundamental properties and dynamical processes requires specialized atomic-level spectroscopy and microscopy, often under in situ conditions. This introductory talk summarizes the central concepts of the preparation, stabilization, and properties of selected low-dimensional materials esp. in view of catalytic applications.

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Glossary

- Catalysis (heterogeneous/homogeneous): Catalysis describes the acceleration of selected reaction routes (via decreased energy barriers) by a reactant activation due to chemical interaction with an active site. In heterogeneous catalysis reactants and catalysts exist in different phases, often involving solid catalysts. In homogeneous catalysis, often molecular complexes consisting of a (metallic) active site surrounded by specially designed ligands are used as catalysts in the same phase as the reactant.
- Dilute Alloy Catalysts: Reactive metals (Pt, Pd, Ir, ...) may be diluted into inert hosts (Cu, Au, Ag, ...) to moderate reactivity and enhance selectivity. Single atoms or smaller ensembles of the active material at the alloy surface can be realized employing thermodynamic driving forces responding to chemical or thermal triggers or kinetic stabilization. Additional elements may be added for further (electronic or geometric) fine-tuning of the active sites.
- Van-der-Waals-Materials: Van-der-Waals Materials are layered compounds consisting of atomically thin layers with strong covalent chemical bonds in the lateral direction of the layer, but weak bonds between these layers. Thus, 2D sheets can be fabricated “top-down” from these materials, e.g. by exfoliation or salt- or ligand-assisted ultrasonication.
- Transition Metal Dichalcogenides (TMDCs): Transition metal dichalcogenides describe a wide and versatile class of materials of the MX₂ stoichiometry (M= Ti, Mo, W, Ta, V, ... and X = O, S, Se, ...). Especially sulfides and selenides often appear as layered van-der-Waals materials and thus are excellent candidates for 2D nanocatalysts, as they combine the rich redox chemistry of transition metals with the special electronic and chemical properties of 2D materials.

Further reading

... on Single Atom Catalysis

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... on 2D Materials in Catalysis

Fan, F. R., Wang, R., Zhang, H. & Wu, W. Emerging beyond-graphene elemental 2D materials for energy and catalysis applications. *Chem. Soc. Rev.* 50, 10983–11031 (2021).

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What a Single Atom Can Do: Identifying and Controlling Active Sites in Electrocatalysis

Megan Jackson, University of North Carolina

A single atom, placed correctly, can help transform simple molecules like water or carbon dioxide into fuel. That transformation happens at "active sites," specific atoms on an electrode surface where the reactions powering fuel cells and electrolyzers actually take place. Identifying and controlling these atoms is one of the central unsolved challenges in catalysis. Active sites are dynamic, hard to modify with atomic precision, and composed of many different types of sites, only a small fraction of which drive most of the chemistry. Making things harder, the spectroscopic signals from active sites are typically swamped by, or indistinguishable from, the signals from ordinary bulk atoms nearby. Identifying which atoms are most active and why would enable bottom-up design of better electrode materials, ultimately leading to faster, more efficient devices for storing and using energy.

This talk covers two complementary strategies for identifying and controlling the atoms responsible for catalytic activity. The first embraces the natural complexity of an electrode surface, using high-resolution microscopy to pinpoint active sites within otherwise disordered surfaces. The second goes the opposite direction: minimizing that complexity through bottom-up electrode design such that the identity and environment of the active sites are known from the start. Together, these approaches show what a single atom in the right environment can do to transform small molecules into fuels.

Background review Articles

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Pursuing a new molecular science through dynamic studies with TEM

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We are living systems, constantly fluctuating and evolving in response to our environment. At the molecular level, matter is also dynamic: atoms and molecules are continuously moving under the influence of thermal fluctuations. Over the past century, photography and video recording have transformed the way humans understand the world. Motion pictures have not only revolutionized entertainment but have also become indispensable tools in science. This naturally raises a fundamental question: *What can scientists learn if we are able to record videos of atoms and molecules?* This question has been a central motivation of my research and will form the basis of this presentation.

In recent years, our research group has developed transmission electron microscopy (TEM) methods capable of visualizing molecular and nanoscale dynamics with high spatial and temporal resolution. These “molecular videos” allow us to observe how atoms assemble into crystals, how catalysts change their structures during reactions, and how nanoscale systems evolve over time. One of our recent discoveries is that chemical transformations at the molecular scale are often non-deterministic.^[1] Processes that appear to proceed along a single pathway in bulk materials can exhibit stochastic behavior when observed at the level of individual particles and molecules.

In this presentation, I will discuss how such direct observations are changing our understanding of chemical phenomena. Particular emphasis will be placed on carbon nanohorns (CNHs), a unique carbon nanomaterial that serves both as a catalyst support and as a nanoscale platform for TEM observation. Using single-site heterogeneous catalysts as examples, I will show how molecular-level imaging provides insights into catalytic mechanisms and dynamic structural fluctuations that are inaccessible through conventional ensemble measurements.^[2] These studies illustrate how observing matter in motion can open new directions in catalysis, materials design, and the emerging field of dynamic materials science

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