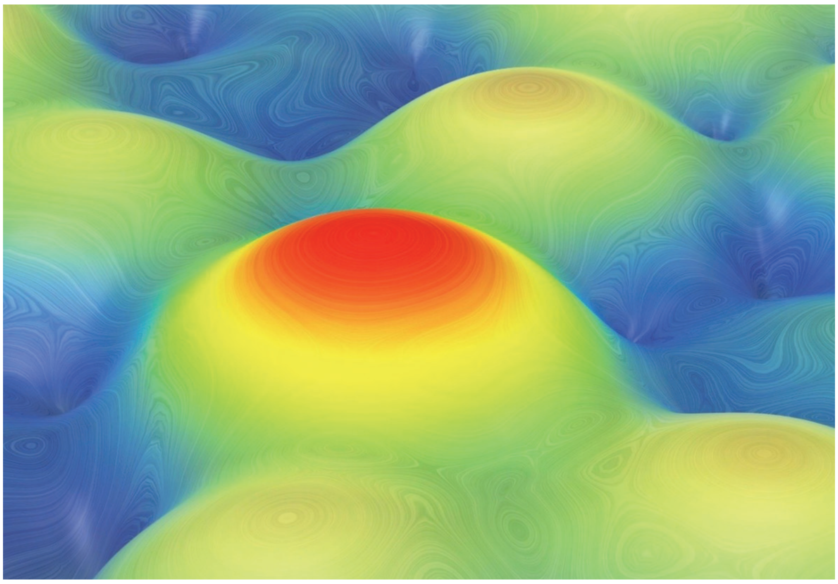
Atomic Catalysts Unlocked by Vintage Theory



Schematic illustration of a single-atom catalysis
(Image by Prof. LU *et al.*, 2025)

Single-atom catalysts (SACs), in which isolated metal atoms such as palladium (Pd) are anchored on solid supports, promise breakthroughs in energy conversion and catalysis. However, balancing their activity (reaction speed) and stability (longevity) remains challenging, as the interplay between metal atoms, supports, and reactants is poorly understood. A team led by Prof. LU Junling at the University of Science and Technology of China (USTC) of the Chinese Academy of Sciences (CAS), along with Prof. WU Xiaojun from USTC and Dr. YANG Bing from the Dalian Institute of Chemical Physics of CAS, has now bridged this gap using a 1950s chemistry concept—the Frontier Molecular Orbital (FMO) theory. Published in *Nature* on April 2, their work reveals how tuning orbital energy levels in SACs can optimize both performance metrics.

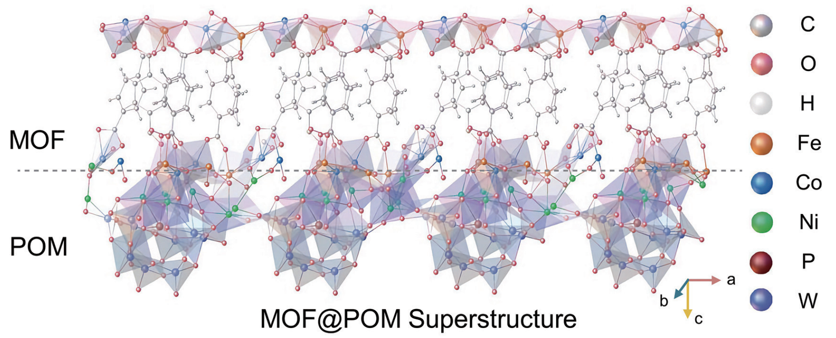
FMO theory simplifies the complex interplay of all molecular orbitals by focusing on two critical "frontier" orbitals: the HOMO (highest occupied molecular orbital) and the LUMO (lowest unoccupied molecular orbital). In a stable molecule under normal conditions, the LUMO always resides at a higher energy level than the HOMO. When two molecules interact, their primary electronic interaction occurs between the HOMO of one molecule and the LUMO of the other. During a reaction, electrons flow from the HOMO (electron donor) into the LUMO (electron acceptor). The efficiency of this electron transfer depends critically on the energy proximity between these two orbitals.

After engineering 34 palladium SACs on 14 oxide supports, the researchers found that shrinking support particles raised their LUMO energy. By shrinking zinc oxide supports to 1.9 nanometers, the team raised the energy of support particles' LUMO, narrowing the gap with palladium's HOMO. This alignment strengthened metal-support bonds (boosting stability) and optimized palladium's LUMO to grab reactants faster—delivering 25.6 min^{-1} reaction rate (20 times faster than conventional SACs) and 100-hour stability.

The FMO-guided design, validated through spectroscopy and microscopy, offers a universal blueprint for SACs. It also accelerates AI-driven discovery of ideal metal-support pairs for clean energy and industrial catalysis.

Breakthrough Catalyst Boosts Water Splitting

Water oxidation—a critical yet sluggish step in green hydrogen production—is a major bottleneck for electrolysis efficiency. Traditional catalysts often degrade quickly under the high current densities needed for industrial scale. Researchers from the CAS Shanghai Institute of Ceramics (SIC), with collaborators, have unveiled a breakthrough catalyst designed for both high activity and remarkable durability. Published in *Science* on April 25, their innovative design starts as a MOF@POM superstructure, crafted by grafting cobalt-iron metal-organic frameworks (MOF) onto nickel-bridged polyoxometalates (POMs). During the water oxidation process, the MOF component transforms *in-situ* into a stable, single-layer cobalt-iron layered double hydroxide covalently bonded to the POM units. *In-situ* analysis revealed that its exceptional stability stems from a dual mechanism—dynamic electron tuning by the POM units and strain relief via covalent nickel-oxygen bonds. This catalyst requires only 178 mV overpotential at 10 mA/cm^2 and powers an electrolyzer achieving 3 A/cm^2 at 1.78 V—surpassing the U.S. Department of Energy's 2025 industrial target. Crucially, it operates stably for 5,140 hours at room temperature with negligible decay and endures over 2,000 hours at 60°C. This design framework bridges lab-scale innovation to industrial-scale water splitting, propelling high-current, low-energy hydrogen production.



The MOF@POM superstructure enables water splitting with high activity and remarkable durability under industrial-level high current densities. (Graphic: SIC)

Flexible Solar Cells Boosted

Flexible tandem solar cells, promising for lightweight power generation, face a hurdle: getting high-quality layers to stick well to rough surfaces like copper indium gallium selenide (CIGS). Scientists have now developed an innovative strategy to improve this, significantly boosting cell performance and durability. As appeared in *Nature Energy* on April 18, a team led by Dr. YE Jichun from the Ningbo Institute of Materials Technology and Engineering (NIMTE), Chinese Academy of Sciences, used an anti-solvent-seeding method to enhance adhesion between the perovskite—a material that efficiently converts sunlight into electricity—top layer and the rough CIGS bottom layer. This approach carefully manages material deposition, ensuring a high-quality interface. Using this method, the team produced a 1.09 cm^2 flexible perovskite/CIGS tandem cell with a certified efficiency of 23.8%—one of the highest for flexible thin-film solar cells. The device retained over 90% efficiency after 3,000 bending cycles and 320 hours of operation, showcasing unprecedented durability. This breakthrough accelerates the commercialization of lightweight, high-performance solar cells for portable and wearable applications.

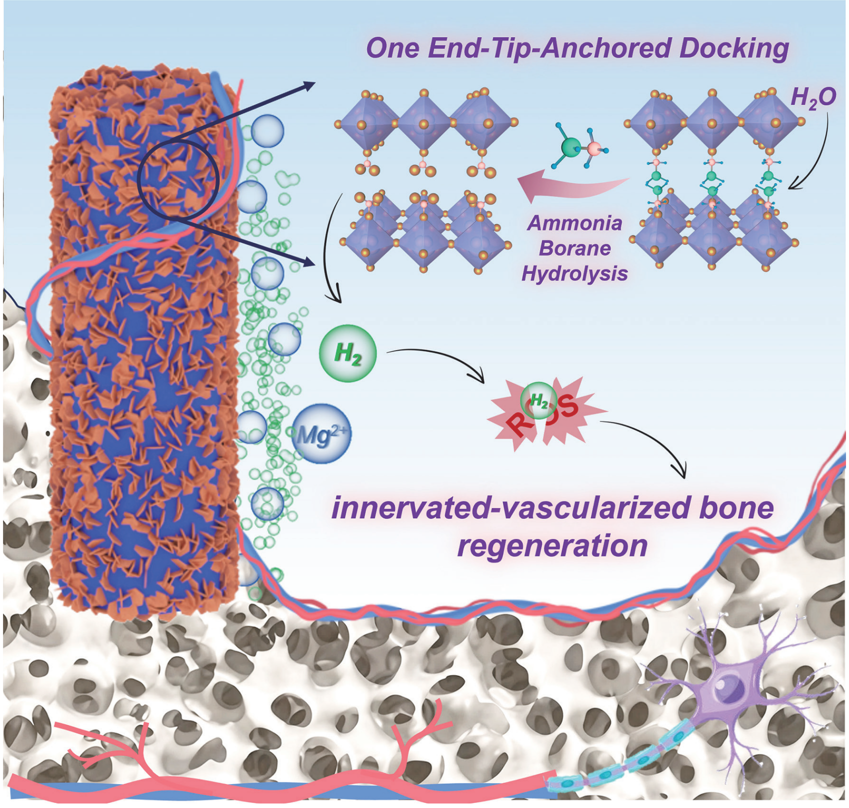
Flexible perovskite/CIGS tandem solar cells developed using the antisolvent-seeding approach. (Graphic: NIMTE)

Hydrogen Heals Diabetic Bones

Diabetic patients often suffer higher orthopedic implant failure rates due to high blood sugar causing inflammation and oxidative stress. While molecular hydrogen (H_2) shows anti-inflammatory and antioxidant promise, current delivery methods lack precision for sustained implant-site treatment. A collaborative team led by Prof. WANG Guocheng from the Shenzhen Institutes of Advanced Technology (SIAT) of the Chinese Academy of Science, Prof. KONG Liang from Air Force Medical University, and Prof. ZHAO Xiaobing from Changzhou University, developed a titanium implant that releases hydrogen directly into bone repair sites. As appeared in *Advanced Materials* on May 3, the researchers developed a novel nanoconfinement strategy featured with a "one-end-anchored docking" mechanism. This confines ammonia borane—a hydrogen-rich compound—within a special titanate nanocrystal coating on the implant.

Key to its success is controlled release dynamics: the nanoconfinement permits only water entry, triggering controlled hydrolysis of ammonia borane. This design ensures steady hydrogen evolution for 11 days-eliminating three critical risks: toxic byproduct leakage, bubble explosion hazards, and H_2O_2-mediated cytotoxicity. Experimental validation confirmed the coating's efficacy in scavenging detrimental reactive oxygen species under high-glucose conditions, concurrently promoting neural regeneration, angiogenesis, and beneficial immunomodulation. Crucially, the sustained H_2 release synergized with magnesium ions (Mg^{2+}) released from the coating to reconstruct neurovascular networks and stimulate bone-forming stem cells.

In diabetic rabbits with bone defects, the implants drove superior bone regeneration alongside robust nerve and blood vessel recovery. The technology also showed promise under normal glucose levels, suggesting wider potential. Unlike rapid hydrogen systems for energy, this innovation uniquely harnesses nanoconfinement for controlled biomedical delivery, specifically revealing the combined power of H_2 and Mg^{2+} for "innervated-vascularized bone regeneration". It offers a transformative strategy for diabetic bone repair and potential applications in neural regeneration and anti-aging therapies.



An innovative titanium implant promotes diabetic bone regeneration through a powerful synergy between sustained H_2 release and early-stage Mg^{2+} delivery. (Graphic: SIAT)

Arginine: Cancer Cells' Double-edged Weapon

Breast cancer cells manipulate a key nutrient to both fuel growth and disable immune defenses—a dual strategy revealed by Chinese scientists. Researchers from the Hangzhou Institute of Medicine (HIM) of the Chinese Academy of Sciences and Sun Yat-Sen University discovered that tumors exploit the amino acid arginine to rewire immune cells into cancer allies.

Researchers found that breast cancer cells pump excess arginine into the tumor microenvironment. While this nutrient typically supports immunity, cancer cells instead use it to reprogram tumor-associated macrophages—immune cells that then suppress cancer-fighting $CD8^+$ T cells. Cutting-edge analysis showed that cancer cell-produced arginine was converted into polyamines in macrophages, driving them into a pro-tumor state. Disrupting arginine to polyamine metabolism restored immune activity and slowed tumor growth in preclinical models. The study, published in *Cancer Cell* on April 3, 2025, proposes combining polyamine blocking drugs with immunotherapy to break this cycle. Though focused on breast cancer, the mechanism may apply to other tumor types.

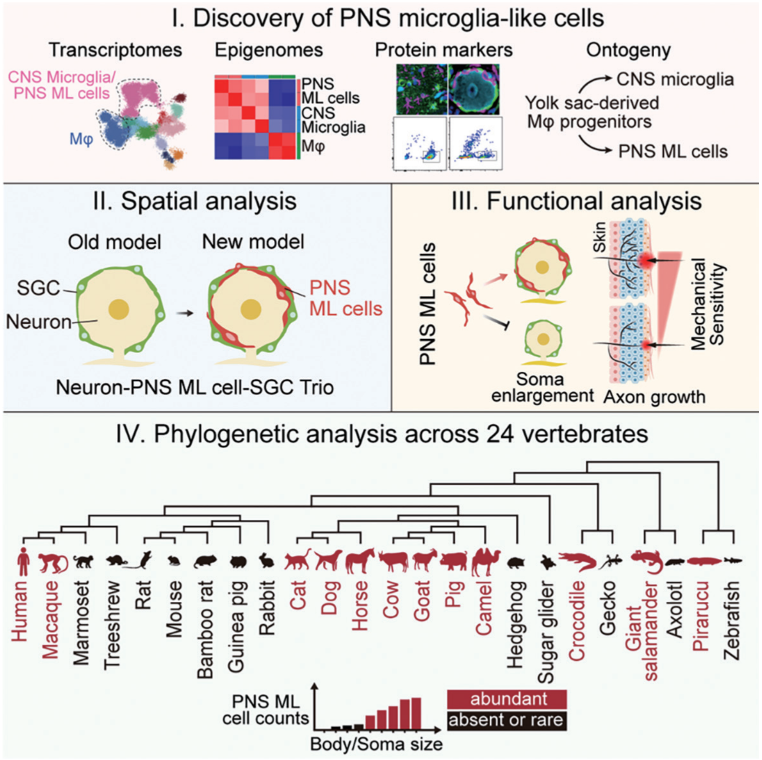
An artistic metaphor of the breast tumor battlefield: Dark, jagged cancer cells exploit swirling blue mist—symbolizing arginine metabolism twists silver macrophages into red traitors—and disable the glowing T-cell warriors' attack. (Graphic: AI generated)

Microglia's Peripheral Power

Microglia—long considered exclusive to the central nervous system—have now been found patrolling the body's peripheral nerves. A team led by Prof. LI Hanjie from the Shenzhen Institutes of Advanced Technology (SIAT), Chinese Academy of Sciences, revealed these immune cells not only exist in the human peripheral nervous system (PNS) but also regulate neuronal size across species. Published in *Cell* on April 7, the study combines single-cell transcriptomics and cross-species analysis to redefine our understanding of neural architecture.

The researchers discovered that PNS microglia share molecular signatures with their CNS counterparts—challenging decades-old assumptions based on rodent models. These cells form a novel trio with neurons and satellite glial cells in peripheral ganglia, replacing the traditional neuron-glia duo model. This structural shift suggests microglia enable rapid responses to neuronal activity changes under both health and disease. Notably, microglia abundance correlates with species' body size and sensory neuron dimensions. Larger animals—like pigs and primates—host more microglia, while smaller species show fewer or none. For example, mice lack them entirely—that is why scientists missed this cell type for more than a century. Evolutionary analysis traces their origin to ancient vertebrates, hinting at selective pressure favoring microglia in organisms with larger neurons.

This work rewrites textbook knowledge of PNS organization and highlights microglia's universal role in neuronal scaling. It may also open new avenues for treating neurological disorders linked to peripheral nerve dysfunction.



The discovery, development, function, and evolution of peripheral nervous system (PNS) microglia. (Graphic: SIAT)

Tool Use by Insect Predator

Tool use—once considered rare in insects—has been documented in a crafty predator. Researchers from China Agricultural University, and two institutions under the Chinese Academy of Sciences—the Xishuangbanna Tropical Botanical Garden (XTBG) and the Institute of Zoology—revealed that the assassin bug *Pahabengkakia piliceps* weaponizes resin from stingless bee nests to trick its prey. Published in *PNAS* on May 12, the study offers the first evidence of an invertebrate predator exploiting social insects' defenses through tool use.

Stingless bees coat nest entrances with sticky resin to trap intruders like ants. Once the invader gets stuck, guard bees swarm to immobilize them. But the assassin bug turns this defense into a lethal trap: it collects resin on its legs, amplifying chemical signals that lure guard bees into attack range. Field trials showed resin-coated bugs achieved a 75% predation success rate—compared to less than 30% for resin-free bugs. Chemical analysis revealed the resin's volatile compounds, not its stickiness, were key to disorienting bees.

"This is a sophisticated manipulation of prey behavior," said Dr. WANG Zhengwei from XTBG. "The bug doesn't just avoid detection—it actively provokes attacks to create opportunities." The bug's reliance on stingless bees for survival likely drove this evolutionary adaptation, challenging assumptions that complex tool use requires advanced cognition.

An assassin bug, coated with resin, raises its fore legs at the entrance preparing to prey. (Image by CHEN Zhaoyang)

Root Bacteria Regulate Rice Tiller Number

Scientists have discovered that root-dwelling bacteria directly control rice tillering—a crucial yield trait—by producing a compound that mimics plant hormones. The study, published in *Cell* on June 12, 2025, reveals how microbes partner with crops to shape agricultural productivity. Researchers analyzed the root microbiota of 182 genetically diverse rice varieties under field conditions. They identified specific bacterial genera whose abundance correlated with tiller numbers, including *Exiguobacterium* (tiller-inhibiting) and *Roseateles/Piscinibacter* (tiller-promoting). Lab and field inoculations confirmed these bacteria causally regulate tiller development.

The root-dwelling bacteria directly control rice tillering by producing a compound that mimics plant hormones. (Graphic: AI generated)

They found, a tiller-inhibiting strain produces a dipeptide called cyclo(Leu-Pro), which mimics strigolactones (SLs)—key plant hormones suppressing tillering. This dipeptide binds directly to the rice SL receptor OsD14, activates the SL signaling pathway. As a result, it reduces tiller numbers by over 50% in multiple rice varieties. Notably, mutant rice lacking OsD14 remained unaffected, confirming this receptor is essential for the bacterial compound's function. Cryo-EM structural analysis revealed cyclo(Leu-Pro) occupies the same OsD14 binding pocket as natural SLs.

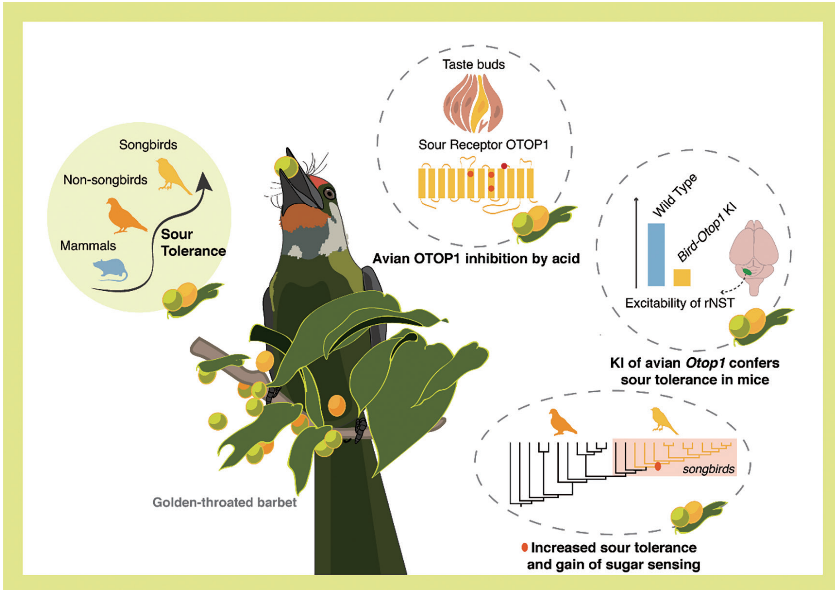
This work uncovers a microbe-hormone signaling axis vital for crop architecture. Harnessing such bacteria could offer new strategies to optimize tillering—and thus grain yield—in sustainable agriculture, reducing reliance on chemical treatments.

Sour Tolerance in Birds

While most mammals find highly acidic foods aversive, many bird species have evolved remarkable tolerance for sour fruits—a crucial adaptation that has opened new ecological niches. Wild fruits can contain organic acid concentrations dozens of times higher than cultivated varieties, yet species like the redwing (*Turdus iliacus*) and black grouse (*Tetrao tetrix*) have evolved to actually prefer these acidic foods as dietary staples.

A new study in *Science* on June 19 by researchers from the Kunming Institute of Zoology of the Chinese Academy of Sciences has uncovered the molecular mechanism behind this evolutionary advantage. Birds' sour taste receptor OTOP1 operates through a unique inhibitory system—under highly acidic conditions, it dampens the neural signals that would normally trigger aversion. When they transferred songbird *OTOP1* genes to mice, sour-related neural activity dropped sharply. Conversely, artificially activating *OTOP1* in birds impaired their natural sour tolerance, confirming the receptor's crucial role.

Songbirds possess an additional genetic mutation (G378) that confers even stronger acid resistance. This enhancement appears to have co-evolved with sweet perception, creating a sensory toolkit that allows birds to exploit a broader range of fruit resources. The timing of this evolutionary development—coinciding with the gain of sweet sensing in songbirds—helps explain the remarkable adaptive radiation of these species.



How birds evolved sour tolerance to thrive on acidic fruits. This adaptation likely underpins the golden-throated barbet's success in montane forests where acidic fruits dominate seasonal diets. (Graphic: ZHANG Hao)

Mice Display Altruistic Rescue Behavior

Researchers have discovered that mice instinctively exhibit rescue-like behavior towards anesthetized companions—a finding that suggests a biological basis for prosociality. The study, published in *PNAS* on April 23, 2025, was led by Dr. HU Li from the Institute of Psychology of the Chinese Academy of Sciences (IPCAS) and Dr. CHEN Zhoufeng from Washington University School of Medicine and the Shenzhen Medical Academy of Research and Translation. The research revealed that observer mice showed signs of stress when near an anesthetized peer and engaged in allogrooming and allolicking, which aided recovery and reduced the observer's stress. The underlying mechanism involves oxytocin (OXT) neurons in the paraventricular nucleus of the hypothalamus, which are activated by the peer's distress signals. These neurons release OXT, which acts on two pathways—one through the central amygdala for emotional processing and another through the dorsal bed nucleus of the stria terminalis for motor actions—to coordinate the rescue-like behavior. This research offers a new perspective on the biological roots of empathy and social connection.

Mice display altruistic rescue behavior towards peers. (Graphic: IPCAS)