

From Reticular Chemistry to Modern Medicine: The Story of the 2025 Nobel Prize in Chemistry

Mohammad Edrisi^{*,1}, Hossein Daneshgar^{**,1,2}

Article Info

Article type:

Popularization of Science

Article history:

Receive Date:
06 May 2026

Revise Date:
18 May 2026

Accept Date:
19 May 2026

Available online:
21 June 2026

Keywords:

Reticular chemistry
Noble Prize in Chemistry
Metal Organic Framework
Biomedical Science

The 2025 Nobel Prize in Chemistry was awarded to the pioneers of reticular chemistry, Omar Yaghi, Richard Robson, and Susumu Kitagawa, for the development of Metal-Organic Frameworks (MOFs). Richard Robson's theoretical work in the 1970s and 1980s was truly pioneering and ahead of its time. He was the first to mathematically and geometrically formulate and publish the concept of constructing infinite coordination networks from molecular building blocks. Yaghi and Kitagawa, independently and concurrently, moved toward constructing such networks driven by practical motivations, such as gas storage and separation, and relying on new synthesis techniques. They were not directly inspired by Robson's theory, but they worked within a broader intellectual framework of which he was one of the architects. This is a field that has brought about a fundamental transformation in the design and engineering of molecular structures over the past two decades. Reticular chemistry entails the design and construction of porous frameworks using predictable intra- and intermolecular bonds, which can be tailor-made for diverse purposes. In addition to MOFs, structures such as Covalent Organic Frameworks (COFs) are also of great interest. Due to their exceptionally high pore volume and surface area, chemical stability, functional tunability, design diversity, and rich host-guest chemistry, these compounds have created unprecedented opportunities in modern medicine, industry, and environmental science. This article, focusing on the achievements recognized by the 2025 Nobel Prize, examines the historical development of reticular chemistry, its chemical foundations, and its biomedical applications, including targeted drug delivery, biosensors, medical imaging, and tissue engineering. An analysis of the accomplishments and operational challenges in translating this technology from the laboratory to the clinic is also presented. Compiled with the aim of reviewing historical developments, the principles of reticular chemistry, and biomedical applications, this article outlines the scientific and practical journey of this molecular revolution.

Cite this article: Edrisi, Mohammad; Daneshgar, Hossein (2026). From Reticular Chemistry to Modern Medicine: The Story of the 2025 Nobel Prize in Chemistry. *Science Cultivation*, 16 (1).62-68.



© Author(s) retain the copyright and full publishing rights.

Publisher: Foundation for the Advancement of Science and Technology in Iran (FAST-IRAN) and Iran Society of Biophysical Chemistry (ISOBC)

* Corresponding Author. Tel: +982161113381, Fax: +982166404680, E-mail: mohammadedrisi@ut.ac.ir

** Corresponding Author. PhD. Tel: +989122053686, E-mail: hossein.daneshgar@ch.sharif.edu

¹ Institute of Biochemistry and Biophysics (IBB), University of Tehran, Tehran, Iran

² Department of Inorganic Chemistry, School of Chemistry, Sharif University of Technology, Tehran, Iran

Extended Abstract

From Reticular Chemistry to Modern Medicine: The Story of the 2025 Nobel Prize in Chemistry

1. Introduction: The Nobel Prize and the Genesis of Reticular Thought

Reticular chemistry, a new field, has opened fresh horizons in designing and engineering porous, functional molecular structures. Its core idea is that molecules can act like building blocks, arranging into repeating 2D or 3D frameworks to form predictable, ordered structures. Emerging in the late 20th century, this concept gave rise to flagship materials like MOFs (Metal-Organic Frameworks), built from metal clusters and organic linkers, and COFs (Covalent Organic Frameworks), formed by strong covalent bonds between organic units. These frameworks boast exceptional properties, high surface area, tunable porosity, and versatile chemistry, leading to groundbreaking applications in energy hydrogen storage, batteries, environmental remediation water purification, gas capture, and biomedicine. In medicine, they can host and deliver drugs, imaging agents, or sensors directly to target cells and can be designed to respond to biological stimuli. The 2025 Nobel Prize in Chemistry awarded to its pioneers underscores the field's profound fundamental and practical impact, heralding a revolution in precise molecular design.

2. The Intellectual Paths of the Three Scientists

2.1 Omar Yaghi: The Architect of Limitless Crystals

Omar Yaghi envisioned and realized the dream of atomic-scale molecular architecture. His revolutionary yet simple idea was to connect atoms and molecules like Lego bricks to create infinite, custom-tailored structures. Founding the field of reticular chemistry, his most famous achievement, MOF-5, broke world records with a surface area of a football field per gram. Driven by a passion for clean energy, Yaghi's work optimizes these frameworks for vast gas storage hydrogen, CO₂ water harvesting from desert air, and targeted drug delivery, transforming chemistry into the art of creating new spaces.

2.2 Richard Robson: The Philosopher of Molecular Bonds

While Yaghi focused on synthesis, Richard Robson laid the theoretical and philosophical foundations. Years before technology allowed their synthesis, Robson systematically conceived the power to predict and design infinite molecular networks. His pioneering work in the 1970s provided the conceptual blueprint, showing that chemistry could evolve from exploratory experimentation into a precise engineering discipline based on geometric rules. His theories became the essential map for navigating this new realm of materials science.

2.3 Susumu Kitagawa: The Discoverer of Dynamic, Flexible Worlds

Susumu Kitagawa revealed the third, astonishing dimension of reticular chemistry: dynamics. While others sought rigid structures, Kitagawa's team discovered that some frameworks could breathe, reversibly expanding, contracting, and changing their pore structure in response to external stimuli like humidity or specific molecules. This discovery transformed MOFs from static absorbents into intelligent, responsive materials, paving the way for ultra-sensitive biosensors, smart drug-delivery systems, and highly selective molecular separation technologies.

Together, Yaghi and Kitagawa discovered a new continent, while Robson had drawn its master map years earlier. The 2025 Nobel Prize rightly honors this trio: two ingenious discoverers who turned a dream into reality and a philosopher of science who framed the dream itself.

3. The Concept of Molecular Networking and the Birth of Porous Frameworks

Molecular networking involves the predictable, ordered bonding of molecules to form extended 3D frameworks. The field rests on two principles: selecting suitable metal nodes and organic linkers, and predicting the structural geometry and symmetry they will form. MOFs, the first highly successful hybrid porous networks, are prized for design flexibility and enormous internal volume. COFs, built via strong covalent bonds, offer high mechanical-thermal stability and rich surface chemistry. Both types provide unprecedented opportunities in targeted drug delivery, medical imaging, and environmental cleanup. Advances in computational design and synthesis over the past two decades now enable the atomic-precision engineering of these networks for specific applications.

4. The Dynamics of Reticular Structures and Engineering Predictable Bonds

A key feature of reticular chemistry is the controllable dynamic behavior of its frameworks. Unlike traditional static materials, MOFs and COFs can adapt and respond to their environment due to bond flexibility and network geometry. By engineering factors like ligand length, node chemistry, and non-covalent interactions, researchers can design frameworks that open-close their pores or change shape selectively. This dynamic nature is crucial for applications like targeted drug release where a drug is released only under specific conditions and biosensing where the framework signals the presence of a target molecule. Computational modeling is essential for predicting and optimizing this behavior before synthesis.

5. From Chemistry to Medicine: Bridging Molecular Networks and Modern Pharmacy

One of reticular chemistry's greatest achievements is its translation into modern medicine. The high internal surface area, controllable porosity, and easy functionalization of MOFs and COFs make them ideal platforms for targeted drug delivery. They can encapsulate drugs stably and release them in a controlled manner at the desired site, reducing side effects and improving efficacy. They also enable the co-delivery of multiple drugs or their combination with imaging agents. This convergence of therapy and diagnostics, known as theranostics, represents a cutting-edge application, allowing for simultaneous treatment and monitoring.

6. Networks in Diagnostics, Imaging, and Targeted Drug Delivery

Porous frameworks have become powerful tools in medical diagnostics and imaging. They can host and selectively release contrast agents or signaling molecules, enabling precise tracking of specific tissues like tumors and enhancing image resolution. A major application is in biosensors, where frameworks are designed to undergo a measurable change in fluorescence or color upon interacting with a target analyte, allowing for early disease detection. In drug delivery, control over pore size and surface chemistry ensures targeted release. Beyond small-molecule drugs, these networks can deliver biological cargo like proteins or genetic material for CRISPR therapies, paving the way for advanced treatments.

7. Critical Perspective and Future Horizons: From Lab to Clinic

Despite significant progress, challenges remain in translating reticular materials to clinical use. Key issues include the stability of some frameworks in physiological conditions in water, scalable and reproducible industrial synthesis, and comprehensive studies on long-term biocompatibility, toxicity, and clearance from the body. However, the future is promising. Furthermore, integrating these networks with other smart nanomaterials and biomolecules is opening paths for sophisticated multifunctional systems. Reticular chemistry stands as a prime example of interdisciplinary convergence, merging chemistry, physics, computation, and biology to create precise structural tools with immense potential to revolutionize human health through next-generation therapeutics, diagnostics, and imaging systems.