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The man of MOFs and more

Ahead of his 60th birthday, Omar Yaghi discussed his life in science so far and where he believes is the exciting space for future developments.

When did you first become interested in science?

I was born in Amman, Jordan, and discovered my passion for chemistry at the age of ten. While visiting our school's library, I remember stumbling upon molecular drawings in a book. I didn't know they were molecules, but as I learned more, I became forever in love with them. This was to be my calling in life. Growing up in modest circumstances, I was encouraged by my father to use education as a pathway to a better life. At the age of 15, I moved to the United States to further my education, eventually earning a PhD in chemistry. My early love for molecular structures laid the foundation for my later interest in reticular chemistry and materials science.

What inspired you to enter academia?

When I was an NSF postdoctoral fellow at Harvard, I found myself at a crossroads, grappling with a decision that would shape my future: should I pursue a career in industry or academia?

Industry promised a much higher salary, but the numbers didn't tell the whole story. In academia, I had the chance to build something truly my own: a lab where I could chase my ideas, conduct meaningful research, and mentor students – opportunities that industry couldn't quite replicate. That sense of intellectual freedom, to discover and innovate on my own terms, lit a fire in me that continues today.

It wasn't an easy choice, especially since I was committed to supporting my parents back home. Academia wasn't necessarily the practical route, but it felt right. For me, the drive to explore the unknown and to help others learn mattered more than financial comfort. And so, I took the leap, prioritizing passion over practicality – and I've never looked back.

How did you decide to focus your research efforts on reticular chemistry and, in particular, the development of MOFs (metal–organic frameworks), COFs (covalent organic frameworks) and related structures?

As a PhD student, I set out to tackle one of the biggest challenges in chemistry: how to design materials with precision. At that time, the process for making extended structures was what we jokingly called the 'shake and bake' approach. Chemists would heat starting materials to extreme temperatures – often over 500 °C – and simply hope for the best. The results were thermodynamic products with very little structural control, and no way to meaningfully modify them once they were made.

This lack of precision frustrated me. I wanted to create extended structures with specific, predictable forms and even tailor them after synthesis. But there was a fundamental obstacle: the crystallization problem. At mild temperatures, linking molecular building blocks with strong bonds usually formed amorphous or poorly defined products.

In 1995, everything changed. We discovered the reaction conditions to link transition metal ions with charged carboxylate linkers to form strong metal-linker bonds. This breakthrough led to crystalline extended structures, and with it, a new era in making solid-state structures. Our work led to the discovery of MOF-5, a structure with ultrahigh porosity that sparked endless possibilities. MOF-5 and its successors unlocked solutions to problems we hadn't even imagined when we started.

What breakthroughs have you been most proud of in your career?

Over the years, I've been fortunate to have made remarkable discoveries with my students: finding the reaction conditions that allowed MOFs to crystallize, designing their structures to achieve permanent porosity, and uncovering the ultrahigh porosity of MOF-5 and its successors. We pushed the boundaries to create MOFs with the largest pore sizes, solved the challenge of crystallizing COFs, and ventured into applications like harvesting water from desert air and designing COFs for carbon capture. And then there's molecular weaving – a concept that once seemed like a distant dream. The moment we succeeded in making these materials, it felt almost surreal, and even now, it continues to amaze me.

Looking back, I feel incredibly grateful for the journey. It feels as though I've spent the past 30 years immersed in a world of molecules, filled with anticipation, excitement, and inspiration at every turn. It's been a privilege to explore these ideas, and I couldn't have imagined a more fulfilling path.

These breakthroughs are not just about scientific impact – their real significance lies in how they offer solutions to some of the challenges our world faces today – sustainability, clean energy, and access to essential resources.

This isn't just my story; it's a testament to the power of collaboration and shared vision. None of this would have been possible without the brilliant minds I've had the honour to work with. Together, we've pushed boundaries, and I'm deeply thankful to have been part of it all.

Have there been many challenges that have surprised you about academia and running a research group?

When we made the first discoveries that opened up this field, I was struck by the wave of skepticism that came our way. Critics seemed to come from every corner, questioning whether what we were doing was even possible. But amidst that noise, there were also a few voices of support – quiet, but unwavering. Those few, yet significant, supporters saw the potential in the work, and their support helped keep us moving forward.

Over time, I developed what I call the 5% rule: when 95% of people doubt you, there's still that steadfast 5% who recognize the value of what you're trying to do. Those are the people you focus on. You take the criticism seriously, but ultimately, you trust your instincts and do what you know needs to be done. The rest – well, you let it go.

One of the most surprising joys in this journey has been working with emerging scholars, graduate students, and postdoctoral fellows. Their energy, curiosity, and fresh perspectives are endlessly inspiring. They remind me why I started this work in the first place: to explore, to learn, and to create something meaningful together.

When did you realize that your research could make the transition from purely academic to industry spinouts?
It was clear to me that when we achieved superior performance for carbon capture and water harvesting that we could create ATOCO, Inc. to commercialize this technology, and when we saw the potential of our results in AI-driven work, we created AIMATX, Inc. to accelerate discoveries for climate applications. Through finding the right kind of team to help build those startups, and raise the funding required to commercialize these applications, we can transform the promise of basic science to societal impact rapidly.

What has surprised you in your involvement in industry and business?
From my limited experience, I've come to understand that while novelty in basic science is vital, it doesn't carry as much weight as the ability to execute and translate that science into something tangible. A groundbreaking discovery in the lab is just the beginning; the real challenge lies in bridging the gap between scientific innovation and real-world application. It's about asking, how does this discovery solve a problem? How can it be scaled, manufactured, and integrated into people's lives?

I've also learned that the market operates on a simple, yet profound principle: when enough people want something, it becomes possible — and often necessary — to make it affordable and widely accessible. Demand drives innovation not just in product design but also in production efficiency, cost reduction, and scalability. What seems expensive and unattainable at first can become ubiquitous if enough people see value in it.

This insight has reshaped the way I view the relationship between science, industry, and society. It's not just about creating something revolutionary; it's about understanding the needs of the people who will use it and finding ways to meet those needs effectively. When scientific discovery aligns with demand, it has the power to create real change — and that's when science truly fulfils its potential.

Have you developed any approaches to best communicate your science to those in academia, industry and beyond?
Communicating scientific discoveries is no easy task. Maintaining scientific accuracy while effectively reaching a broad audience, especially non-experts, is a constant balancing act. Whenever I share my research, I find myself returning to a critical question: Why should those outside my field care? And, even more fundamentally: Why should people on Main Street care?

Answering these questions is at the heart of good science communication. It challenges me to frame my work in terms that resonate with everyone, distilling complex ideas without losing their essence. This approach has shaped how I craft my messages, ensuring they are not only understandable but also meaningful to diverse audiences.

I'll admit, I haven't always succeeded in this endeavour. Science can be dense, nuanced, and, at times, difficult to translate into universally relatable terms. I've learnt that effective communication is as much about empathy as it is about clarity. And while it remains a work in progress, this mindset has made a significant difference in how I approach sharing my discoveries with others.

What do you see as the exciting areas for future research in this field?
Reticular chemistry stands at the threshold of a transformative era. Its ability to enable the precise design of chemical structures and materials — and even their post-synthetic modification with the same level of precision — ushers in a future where custom-made materials tailored for specific functions will become the norm.

I envision the seamless integration of AI and large language models becoming a driving force behind accelerated discovery. These tools are not just enhancements but essential catalysts, linking complex structures to targeted functions with unprecedented efficiency. The synergy of AI and reticular chemistry holds the power to revolutionize the way we design, understand, and deploy materials.

Imagine a world where AI-guided reticular synthesis not only speeds up the discovery process — from years to mere weeks, as we've already demonstrated with COFs — but also scales this groundbreaking chemistry on a global level. We've shown that an AI-driven reticular synthesis cycle can double the rate of discovery compared to traditional methods. Now, picture this multiplied across laboratories worldwide, with AI weaving together data, insights, and expertise into a unified, global effort to solve humanity's greatest challenges.

Reticular chemistry research will be expanded by the fusion of human ingenuity and artificial intelligence, creating a world where chemistry not only keeps pace with our needs but anticipates them.

What changes have you noticed in the culture of science over your career and how do you think it will continue to change?
In my lab, I've observed a growing demand from students for the modernization of chemistry, particularly the integration of AI and robotics. Recognizing this shift, we are now combining advanced AI tools with experimental science, to streamline laboratory tasks and accelerate discoveries.

This shift is not optional — it is essential. Chemistry must adapt to remain relevant and competitive in a rapidly evolving scientific landscape. The traditional methods, while foundational, no longer resonate with today's students or inspire the most creative professors. The reality is clear: to thrive in the future, chemistry researchers must fully embrace AI tools, harness their potential, and develop fluency in this transformative arena. Those who resist this change will risk being left behind in a field that is advancing faster than ever before.

This is more than just a call for modernization; it is a matter of survival for chemistry as a discipline. Chemistry has long been regarded as the 'central science', but that is no longer enough. Central is not frontier. Chemistry must redefine itself as a frontier science, pushing boundaries, embracing new technologies, and leading innovation. It is by embracing the frontiers that we will secure the future of this vital field, inspiring the next generation of scientists and ensuring its continued relevance in solving the challenges facing society.

What advice do you give to the next generation of scientists?
Be fearless. Dive into the experiment, even if the odds of success seem slim. Experimentation is the very essence of hope — it's the spark that ignites discovery and transforms how we think, solve problems, and shape the future. It is humanity's most powerful tool for progress.

Forget about following the crowd or sticking to the so-called blueprint for success. True breakthroughs don't come from playing it safe or following someone else's map. Instead, chart your own course. Step away from conventional paths, and don't be afraid to question your field's dogmas or challenge what is deemed acceptable. The most rewarding discoveries often lie beyond the boundaries of what seems possible.

Taking risks isn't just an act of bravery — it's an invitation to adventure. The journey may be uncertain, but the rewards are immeasurable: the thrill of uncovering something new, reshaping perspectives, and knowing you've contributed something unique to the world. Blaze your own trail, trust your instincts, and embrace the unexpected. That's where the magic of science — and life — truly begins.

One more thing: in everything you do, remember that there are always those less fortunate than you. Reaching out to help others isn't just an act of kindness — it's an opportunity for growth. When you engage with those in need, you gain new perspectives, broaden your understanding, and elevate your thinking.

Giving is never a one-way street. It creates a powerful exchange of ideas, experiences, and empathy that enriches both the giver and the receiver. By connecting with people from different walks of life and cultures, you'll not only make a difference in their lives but also become a better, more compassionate human being.

What is next for you?

I envision pushing the boundaries of reticular chemistry further and advancing the frontiers of chemistry as a whole. My goal is to deepen the integration of chemistry, computer science, and engineering to bridge the gap between basic science and societal needs. I am particularly passionate about continuing to shape a new discipline that combines AI, chemical synthesis, and climate solutions.

Ultimately, my dream is to create a seamless connection between three critical cycles: the cycle of basic scientific discovery, the AI-driven cycle of accelerated innovation, and what I call the scaling cycle — the process of translating discoveries into global solutions. Together, these interconnected cycles have the potential to redefine how science impacts society at every level.

Omar Yaghi was interviewed by Stephanie Greed

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Competing interests

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