INNOVATOR PROFILE

2019 Innovator of the Year
Omar Yaghi

By Patricia Miller

Scientific advances transform our lives in miraculous ways. For chemist and UC Berkeley professor Omar Yaghi, his pioneering work has already impacted countless lives and will continue shaping the development of mankind for centuries to come. He's published more than 300 scientific articles, which are referenced so frequently that he is among the top five most highly cited chemists in the world.

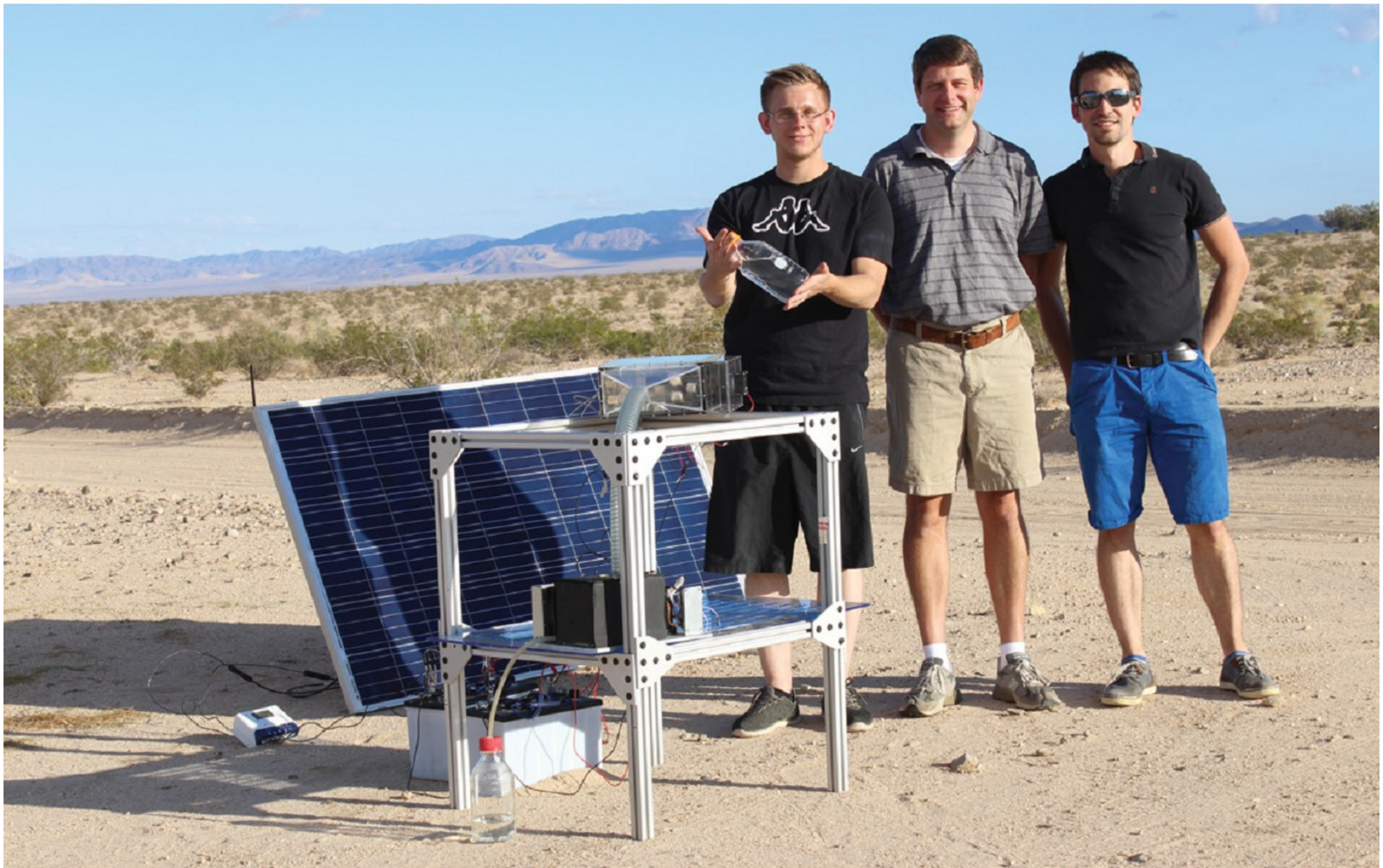
In the 90s, Yaghi developed a fascinating chemical structure known as the MOF, or metal-organic framework. In so doing, he also created a new field of chemistry known as reticular chemistry, which unifies inorganic and organic chemistry into a comprehensive field of research.

What's so special about MOFs? They can be customized to absorb any vapor and release that vapor later with very little energy input. He's pioneered MOFs that can absorb hydrogen, carbon dioxide, natural gas, and now – water.

Though there are plenty of materials that can absorb water, MOFs can absorb water from air with very low humidity and, once heated slightly, release that vapor in the form of drinkable water. His systems capture water from the air at night and then, using solar power to raise the temperature of the material to 45 degrees celsius, release that water to be collected for use.

"We were the first to do hydrogen storage, methane capture, carbon dioxide capture, and now water."

Omar Yaghi (center) with students in the laboratory.



(Above) A photo of the latest field trial for "water harvesting from desert air" (pictured are research team members with a MOF water harvester collecting water from air in the Mojave Desert – the driest desert in North America).

Drought-stricken regions and naturally arid climates are desperate for this type of technology, and as the climate crisis continues to escalate, technologies like Yaghi's could hold the key to providing water for thirsting nations or for capturing greenhouse gases from the atmosphere, and that's just the tip of its capabilities.

We spoke with Yaghi to learn what sparked his early passion for science, what message he has for the next generation, and what led him to such a revolutionary discovery.

***Innovation & Tech Today*: How did you first become interested in chemistry?**

Omar Yaghi: I became interested in chemistry when I was a kid. I was 10 years old and went into a library where I found a book that had drawings of molecules, which I didn't know anything about. I didn't even know that there *were* molecules, but the drawings looked complex and interesting and so they captured my attention. I kept that with me. Later I learned they were molecules, and so it became my favorite topic.

It's strange how a passion for things develop, but it's also strange how we pick the things we pick. I was very interested in knowing, "What is this?" "What is behind things?" "Why do things look the way they do?" And so as a child, I was very interested in what is behind what you see, what is it made from? Why do things appear the way they do; what are the smaller and smaller parts of matter? That's why chemistry was just so captivating to me.

***I&T Today*: Why are MOFs significant?**

OY: MOFs are the real estate onto which you can bind molecules and gases, like hydrogen, methane, carbon dioxide, and the latest is water. We showed that MOFs can be permanently porous, meaning when you evacuate their pores, the structures don't collapse but remain open. So the [first MOF we developed] had a surface area that broke all records of porosity. All previous records, everything that humanity has ever made, this [porosity] was much higher, and we've continued to break our own record many times since then.

This is not just a material that has porosity. Behind this material is a new chemistry that has been a fountain of new materials: reticular chemistry, which is the chemistry of the strong bond and how to control the strong bond in infinite extended structures.

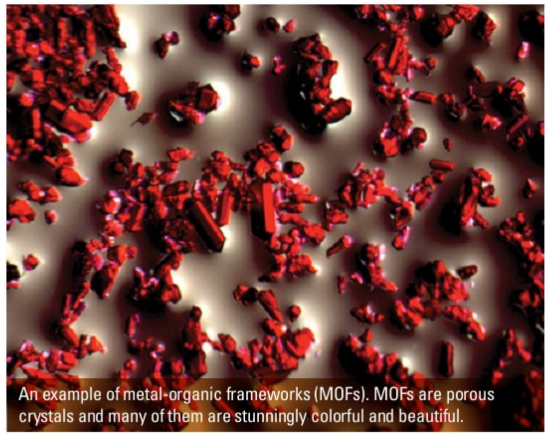
***I&T Today*: In many cases when reporting on scientific discoveries, there is fantastic work going on at a deeper level, but often all we talk about are the applications of that knowledge.**

OY: Yes, when you say, "Oh, I can harvest water from desert air and deliver water." That's a very important thing to be able to do and the public likes to hear these things because they can relate to them. Not very many people outside of chemistry are interested in well, "how was this generated?" And the way it was generated is that somebody like me, who was more interested in basic science than applications, especially when we started this research… I was more interested in answering an intellectual challenge, which was, how do you make materials using a building block approach? How do you turn chemistry into LEGOs?

I took that risk as an assistant professor with the hope of tenure one day; I took this big risk that paid off. Once we made [MOFs], once we demonstrated that you can build structures by molecular building blocks, we realized the potential is great. We were the first to do hydrogen storage, methane capture, carbon dioxide capture, and now water.

***I&T Today*: I'm fascinated that water storage wasn't your intention when you started. You grew up in an arid region and obtaining water was a persistent problem for your family, and somehow, without intending to, you've developed this technology that can be applied to solving that problem.**

OY: I think it also brings up another very, very important point, and that is the way great things happen in science is by answering intellectual questions, not necessarily picking a societal problem and trying to find a solution to it. Meaning, when you solve an intellectual challenge, it branches out into an infinite number of things that you can do for society. But if I started out with water from air, I would have to work backwards and then think, what materials are available that I could do that with? Well, I would never have invented MOFs. Never. Because I would have been in an engineering mode, where you use existing stuff to test whether it's going to be good for harvesting water or carbon dioxide, and that would have never worked. Those materials wouldn't have the new properties that emerged from the new materials that we've invented as a result of answering an intellectual problem.



An example of metal-organic frameworks (MOFs). MOFs are porous crystals and many of them are stunningly colorful and beautiful.

***I&T Today*: Perhaps that's why it's so important to instill those ideals in children, through STEM: instead of thinking about the end results, be willing to ask questions and be curious.**

OY: One of the biggest mistakes we make when we teach younger kids – I call them emerging scholars – is to assume that if we don't give them a practical thing that they can think of, like harvesting water from air, I'm not going to get their attention. It turns out everyone, young or old, is stimulated by good questions.

I was really more intrigued with the question of, "Could I develop chemistry where I can use the infinite number of molecular building blocks that exist as my starting materials and stitch them together into extended structures?" And that was the intellectual question that was our motivation. My motivation wasn't necessarily directly to save mankind through carbon capture, but I knew very well that if I succeeded in answering that basic question that there would be many interesting and fascinating applications that could solve some big problems in society.

***I&T Today*: If you didn't intend to create a material with these capabilities, when did you realize MOFs could harvest water from dry air?**

OY: We were working on carbon capture. We made a material and then designed its interior so that it specifically can take up CO2 and the presence of water actually helps the binding of CO2. Then we noticed there were certain structures that took up water in a way that was very special. They were taking up water at 20 percent relative humidity.

Of course, there are materials that take up humidity at 20 percent, like zeolites, but the special thing about this material is that you can also take the water out easily at mild temps. I think it was 45 degrees celsius. But for zeolites and minerals, you have to heat them up to 300 degrees celsius to remove the water. So you couldn't use them in the end to capture water from air and then deliver drinking water because you would have to apply so much energy.

That was one of the most powerful things we noticed; you can not only capture the water at low humidity but also take it out at mild temperature, almost the temperature of the desert during the day.

So we looked at this and I said to my students, "This would be perfect for binding water from the atmosphere at night when it's a little bit more humid. Then, during the day when it's hot, you can remove the water and, if you have a way to condense that vapor, deliver drinking water. And that was the beginning of the water harvesting project. ■

For more fascinating insights from Omar Yaghi's interview, check out www.innotechtoday.com/Yaghi.