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EDITORIAL

Design, Synthesis, Action! Molecular Machines Take the 2016 Nobel Prize in Chemistry

The adage "a picture is worth a thousand words but a video is worth a million" was reinforced earlier this month when the 2016 Nobel Prize in Chemistry was awarded jointly to Jean-Pierre Sauvage, Sir J. Fraser Stoddart, and Bernard L. Feringa for the design and synthesis of molecular machines. This award brought none of the familiar controversies regarding whether the discovery honored was *really* chemistry (or, rather, biology or physics). Molecular machines are squarely the creation of chemists—organic chemists in this case—and, while tiny, they are monuments to human creativity. We chemists have a rich history of accomplishments in molecular construction, artfully putting together molecules found either in nature or in our imaginations a few atoms at a time. Often the challenge lies in complex patterns of functionality, stereochemistry, and connectivity. And these constructions are complicated enough. But molecular machines have the additional dimension of motion. In this regard, the Nobel Prize winners brought a moving pictures revolution to the field of organic chemistry. Movies starring molecular machines unveil a world where molecules are designed with autonomous functions, sometimes modulated by external stimuli such as light, metals, electrons, or protons. They switch, ratchet, rotate and drive (reviewed in this comprehensive *Chem. Rev.* article from 2015). This year's Nobel Laureates paint a picture wherein these molecules work for us in next-generation computers, energy conversion materials, and delivery of drugs to cancer cells.

But no matter their envisioned applications, which even their creators predict lie in a distant future, the pursuit of molecular machines with increasingly complex capability has necessitated conceptual and technical breakthroughs that ripple into many other areas. This is, after all, the very nature of basic science—rarely can we know a discovery's potential impact within a generation, and often that impact is felt most strongly in unforeseen venues. In the here and now, we can celebrate molecular machines for focusing attention on the mechanical bond with its unique properties and synthetic challenges. And on driving advances in spectroscopy that were needed to characterize interlocked or rotating ring systems in motion. Molecular machinists have certainly benefitted from parallel advances in nanoscale imaging, and, likewise, those aspiring to build nanoscale-architectured materials from the bottom-up would do well to consider some of these tiny molecular machines as building blocks. Also, understanding the forces and energetics underlying a molecular machine's performance may shed light on how biological machines work, such as vesicle transport complexes, polyketide synthases, and the ribosome. Unlike their synthetic cousins, these natural molecular machines are difficult substrates for structure–activity relationship studies.

The spotlight of the Nobel Prize also illuminates the global nature of science, with this year's Chemistry Laureates collectively having trained or worked in at least five countries, both in academic and industrial settings. Prof. Sauvage completed his Ph.D. at Université Louis-Pasteur (with 1987 Chemistry Nobel Laureate Jean-Marie Lehn), then pursued postdoctoral work at Oxford University in the UK before returning to France to join the faculty at University of Strasbourg. Prof. Feringa, trained in The Netherlands, had a productive 6-year career in industry both in The Netherlands and the UK before returning to University of Groningen as a lecturer then professor. And Prof. Stoddart trained in Scotland and Canada and held several university and industry positions in the UK and the US, culminating in his present faculty position at Northwestern University. Their accomplishments were enabled by a free flow of ideas and co-workers across borders. Their own laboratories celebrate international diversity and flow. Scientists from around the world, including our own Senior Editor Chris Chang, have come out to say they enjoyed time in the laboratory of Prof. Sauvage. Prof. Feringa currently has trainees with 18 different nationalities, while Stoddart's current group hails from 10 countries, including an Iranian scientist, a group for whom it is incredibly difficult to travel internationally.

Published: October 13, 2016

In a recent interview with The Guardian, Stoddart responded to questions about the consequences of "Brexit" that "anything that stops the free movement of people is a big negative for science." The international teams that created molecular machines provide a clear, bright example of global science at its best and, one hopes, a model to uphold in the future.

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DOI: 10.1021/acscentsci.6b00302
ACS Cent. Sci. 2016, 2, 674−675