Young Career Focus: Professor Brian Northrop (Wesleyan University, USA)

Background and Purpose. SYNFORM regularly meets young up-and-coming researchers who are performing exceptionally well in the arena of organic chemistry and related fields of research, in order to introduce them to the readership. This Young Career Focus presents Professor Brian Northrop (Wesleyan University, USA).

Biographical Sketch

Prof. B. H. Northrop

Brian Northrop is originally from Prince George's County, Maryland (USA). He obtained his bachelor's degree from Middlebury College in Middlebury, Vermont (USA), in 2001 while working in the lab of Professor Jeff Byers. In 2002, he began his graduate work at the University of California, Los Angeles (USA), where he worked jointly with Professors Ken Houk and Fraser Stoddart. After obtaining his PhD in 2006, he joined the research group of Professor Peter Stang at the University of Utah (USA) as an NIH Postdoctoral Fellow. In 2009, he joined the faculty of Wesleyan University (USA) where he was promoted to Associate Professor in 2015. Professor Northrop has received an American Chemical Society Petroleum Research Fund (ACS-PRF) New Doctoral Investigator Award, a National Science Foundation (NSF) CAREER Award, and the Thieme Chemistry Journals Award.

INTERVIEW

SYNFORM *What is the focus of your current research activity?*

Prof. B. H. Northrop My research group and I are focused on developing new and efficient methods for synthesizing complex organic materials from relatively simple starting materials. Our approach takes advantage of a combination of techniques that are fundamental to both classical and contemporary physical organic chemistry, such as molecular and supramolecular self-assembly, dynamic covalent chemistry, and highly efficient 'click' chemistry. Our current research is focused in two predominant areas: (i) the development of selective, orthogonal thiol-Michael reactions to enable the rapid synthesis of multifunctional macromolecules; and (ii) understanding and optimizing the dynamic covalent assembly of boronic acids to allow for the *de novo* design of discrete, nanoporous materials.

SYNFORM *When did you get interested in synthesis?*

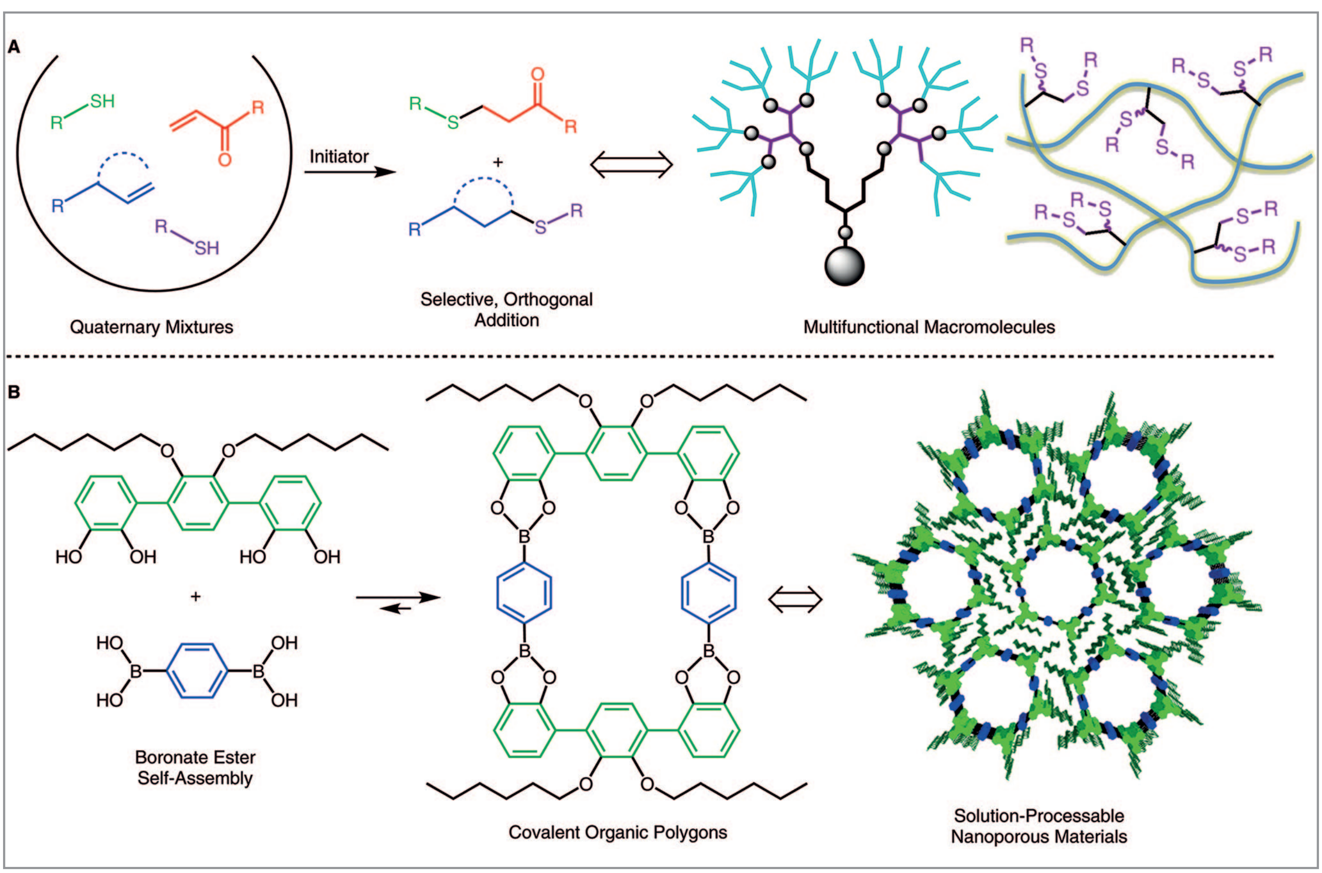
Prof. B. H. Northrop I entered college with a lot of interest in chemistry but I wasn't sure whether I wanted to major in it, partly because I had not yet had exposure to organic chemistry. Once I took organic, however, the major was a foregone conclusion. I saw organic chemistry as built upon all the foundational physical principles that I loved about general chemistry and physics but applied to the construction of molecules in a way that felt, to me, like a combination of problem-solving, art, and design. I joined a research group and loved independent research despite the fact that many (most?) of my synthetic routes failed. In fact, I enjoyed independent research more than undergraduate lab courses *because* many of my reactions didn't work – often times much more can be learned from a failed reaction than a successful one. I found, as I imagine most chemists do, that the further I went in research the more questions I had and the more interesting they became. That initial undergraduate research experience motivated me to continue in chemistry not just as my major but also as a career. Additionally, I have been very fortunate throughout my undergraduate, graduate, and postdoctoral studies to have had advisors who pushed me to think deeply and critically about my research while also being incredibly supportive.

SYNFORM *What do you think about the modern role and prospects of organic synthesis?*

Prof. B. H. Northrop I find it amazing to think about how far the art and science of organic synthesis has come over the past century. One can easily fall into the trap of thinking that with so much progress we are now only making incremental advances in highly specialized areas. I couldn't disagree more. One of the most incredible aspects of organic synthesis is the fact that it is boundless, limited only by our creativity, imagination, and resources (and the laws of thermodynamics). New molecules, new materials, and new synthetic methods that may previously have been considered prohibitively difficult may be discovered at any time. For example graphene, once believed unstable, can now be manufactured on an industrial scale. Similarly, recent advances in C–H functionalization have the potential to revolutionize chemical synthesis from pharmaceuticals to manufacturing to consumer goods. Furthermore, the role of organic synthesis is not limited to specialists in the area; rather it is impactful across the sciences. Research advances in biology, physics, engineering, environmental sciences, etc. are often beneficial to and help promote new developments in organic synthesis just as new synthetic developments frequently impact research in other sciences. This centrality of organic synthesis highlights the value of collaborative, cross-disciplinary research.

SYNFORM *Your research group is active in the areas of organic synthesis and organic materials. Can you tell us more about your research and its aims?*

Prof. B. H. Northrop Our research in the area of thiol-Michael 'click' reactions focuses on understanding and optimizing the selective addition of a given thiol to a given Michael



Scheme 1

acceptor. While thiol-Michael reactions typically proceed in high to quantitative yields with great tolerance of different functional groups and solvents, mixtures of several thiols and/or Michael acceptors (i.e., ternary or quaternary reactions) generally lead to mixtures of thioether products. My group is using a combination of computational modeling and experimental test reactions to screen myriad combinations of reaction conditions to elucidate the fundamental influences that solvent, initiator, and thiol and Michael acceptor functionality play on the energetics, kinetics, and selectivity of thiol-Michael reactions. To date we, and others in this area, have found several means of achieving complete selectivity in mixtures of thiols and Michael acceptors (Scheme 1A). Most recently, students in my group have developed reaction conditions that promote the pairwise addition of two different thiols to two different Michael acceptors within quaternary reactions. My group then takes advantage of these selective thiol-Michael reactions to prepare complex macromolecules such as multifunctional polymers, layered dendrimers, and mechanically interlocked polymers.

My group is also investigating the self-assembly of boronic acids, both with themselves and with aromatic donors such as catechol and *o*-phenylenediamine derivatives. We have, for example, synthesized a variety of polycyclic aromatic bis(catechol) derivatives that, when combined with aryl diboronic acids, dynamically assemble into nanoporous covalent organic polygons (Scheme 1B). These boronate ester polygons can be considered discrete analogues of ‘infinitely’ periodic covalent organic frameworks (COFs). Our aim is to use these solution-processable covalent organic polygons to better understand the assembly mechanisms and structure–function relationships of insoluble COFs. We are also using synthesis and theoretical modeling to investigate the influence of extended conjugation on the electronic properties of oligomers and polymers of boronate ester and diazaborole assemblies.

SYNFORM *What is your most important scientific achievement to date and why?*

Prof. B. H. Northrop Currently, I think the greatest impact of my group’s research is more a matter of approach than a specific result. By this I mean that we approach research projects working across each of the ‘three M’s’ of chemistry: making, modeling, and measuring. This complementary blend of synthesis, analysis, and theory provides my group with a deep, fundamental understanding of the chemical reactions and processes we are interested in. From this understanding comes the ability to develop and control everything from chemical reactivity to supramolecular assembly in a rational manner. Examples of this multipronged approach include our investigation of the mechanism and selectivity of thiol-maleimide reactions (*Polym. Chem.* **2015**, *6*, 3415) and our elucidation of the vibrational properties of boronic acid derived assemblies (*Chem. Mater.* **2014**, *26*, 3781). It is my hope that our approach to research and our initial published work have laid a solid foundation for a variety of more important scientific achievements in the future.