Winter 2017

In this Issue:

• Magnetic tweezer reveal hairballs in polymer growth
• Innovations In chemistry education help undergrads
• Measuring tool probes solar cell materials
Letter from the Chair

Welcome to C&CB News, the resurgent Newsletter for the Department of Chemistry and Chemical Biology. It has been over a decade since we last published a newsletter. Going forward we hope to produce issues at least once a year. C&CB News is part of our focus in reconnecting the department with the many alumni and friends who have passed through the halls of Baker Laboratory. In that spirit, it is my pleasure to share some of the wonderful and exciting things that are going on within the department.

The C&CB faculty currently comprises 18 full professors, 1 associate professor, 9 assistant professors and 12 emeritus faculty members. Chemistry is in the midst of a major hiring initiative: the College, in collaboration with the Provost, has committed 11 new positions for C&CB over a three-year period. Tristan Lambert, currently a Full Professor at Columbia University will be joining us January 1, 2018; and Nozomi Ando, currently an Assistant Professor at Princeton University, will arrive July 1, 2018. Furthermore, Frank Schroeder, a chemical biologist at the Boyce Thompson Institute, will be assuming a dual appointment as a Full Professor in C&CB and BTI. Over the past six years, our faculty ranks have grown with the inclusion of nine junior faculty members. Nandini Ananth, Yimon Aye, Jeremy Baskin, Robert DiStasio, Brett Fors, Kyle Lancaster, Song Lin, Poul Petersen, and Justin Wilson joined the department at various times between 2012 and 2015. Some of the accomplishments of these individuals will be the focus of articles appearing later in this newsletter. We pride ourselves in hiring effectively at the junior level. Our most recent external review (2013) concluded that, “perhaps no department in the nation has had greater success in identifying and recruiting talented assistant professors.”

Case in point, our newest faculty member, Song Lin, has hit the ground running since arriving on campus in July 2016. He has worked hard to establish his research group, set up laboratories and begin the process of developing an independent research program. Professor Lin’s field is organic chemistry and his specific interests are in electro-synthesis, and organic materials. We are extremely happy to have Song on our faculty and look forward to his future contributions to both chemistry and the department. Read more about his exciting work later in the newsletter.

Our faculty members continue to receive broad recognition for their work. This past year Geoffrey Coates was elected to the National Academy of Sciences. Jeremy Baskin received a 2017 Beckman Young Investigator Award. Nandini Ananth was recognized for her teaching efforts with a 2017 CU Award for Excellence in Teaching, Advising and Mentoring of Graduate and Professional Students. Yimon Aye’s dedicated efforts have resulted in several prizes, most notably the 2017 Buck Whitney Award of the American Chemical Society. Kyle Lancaster was awarded a 2017 Alfred P. Sloan Foundation Fellowship. Lecturer Thomas Rutledge was honored with the 2017 Stephen and Margery Russell Distinguished Teaching Award. This year also saw major symposia at international meetings in honor of our emeritus faculty: Roald Hoffmann, Jerry Meinwald and Ben Widom.

The year was not without losses. David Usher, a long-standing professor of our department, passed away in October just shy of his 81st birthday. David joined the Cornell faculty in 1965 and taught generations of organic chemistry students. His research focused on the chemistry of nucleic acids and proteins and had implications for how the chemistry of life originated and whether it could be supported elsewhere in the solar system. Robert Hughes, Professor Emeritus, passed away in April at the age of 92. Professor Hughes earned his PhD in the department in 1952, and returned in 1964 as a professor of chemistry. Dr. Hughes was a leader in the field of materials chemistry throughout his career. In February, Earl Peters died peacefully in his sleep at the age of 89. Earl was the Executive Director of the department for 28 years. Since retiring in 2001, he remained active as a true ambassador for C&CB and Cornell.

In 2017, 39 outstanding students graduated with the new chemistry major, which was revamped following a curriculum review in 2013. Nearly all of these students had research experience during their time at Cornell. Of all students at Cornell, ~60% will take at least one chemistry course during their degree. C&CB has incorporated recent pedagogical advances into several preparatory classes to give students the quantitative reasoning skills necessary for success in the physical sciences. Led by Prof. Stephen Lee, students enrolled in CHEM 1070 and 1080 undertake a combination of flipped classes, peer-assisted workshops, and scored practice exams. Improved outcomes are quantifiable and especially evident for underserved students. Such active learning techniques have also been incorporated into the Pre-Freshman Preparatory (PSP) program. To further encourage underserved students to pursue careers in research and medicine, we have developed the Cornell-HHMI Accelerating Medical Progress through Scholarship (CHAMPS) program, which is supported by the teaching efforts of Prof. Lee and Dr. Tom Rutledge. So far, over 60 students and 30 different Cornell research laboratories have participated in CHAMPS.

The incoming graduate class (2017) is 40 strong, and one of the larger classes in recent memory, being over 50% larger than the previous year’s class of graduate students. We used 7 Graduate Fellowships and one Dean’s Excellence Fellowship to help in our recruiting efforts. I am greatly appreciative of the efforts of H. Floyd Davis, our Director of Graduate Studies, in stewarding our graduate program.

During the first two years of their studies, many of our new graduate students will assist in the department’s teaching activities, serving as Teaching Assistants (TAs) in one of the lecture or lab classes taught each...
semester. The Department remains a fixture in the undergraduate education efforts at Cornell University. Close to 40% of the incoming freshman class will take a course in Chemistry during their first year.

A continuing challenge for the Department is in securing funding for our advanced graduate students. The department continues to pursue external fellowships for our current graduate students. It is these young scientists who perform the cutting edge research for which our department is famous. Many of these same students attend a class with grant preparation as a major component and the payoff has been substantial. This past year our students garnered fellowships from the American Heart Association and National Science Foundation. Other students are on fellowships from other organizations, including the National Institutes of Health and the Howard Hughes Medical Institute. Our success with student fellowships mirrors the ability of the department to fundraise from the federal agencies and industry. C&CB accounts for ~50% of the externally funded research in the College of Arts and Sciences. That said, additional named Graduate Fellowships would be very useful in supporting both our pedagogical and research goals.

While our teaching and research efforts remain strong, our faculty size is currently well below our historical levels. As described above, we are doing our very best to bring to Cornell the strongest candidates at all career stages. This spring we are looking to make both junior and senior hires in all fields within the Department, with special emphasis in Organic and Physical chemistry. Thus, there is much to keep us busy. Despite our many achievements, an even higher level of research and scholarship beckons. I would like to thank you for reading so far, and hope that you enjoy the rest of this publication.

– Brian Crane

Gifts of all sizes are powerful investments in Cornell’s mission and in the Chemistry Department’s future programming. Your donation helps to educate deserving students, strengthen research that leads to new knowledge, prepare tomorrows leaders, and serve the public good.

Mail your contribution to:

**Cornell University**
Department of Chemistry and Chemical Biology
P.O. Box 37334
Boone, IA 50037-0334

We are very grateful to our many friends who have so generously supported the Department. In the past year, contributions have supported the creation of a named Chair in Chemistry, and an award that issued to one outstanding undergraduate chemistry major. Both of these examples directly impact our department, and our students, on a daily basis.

Give online: chemistry.cornell.edu

C&CB is now on Facebook & Twitter!

Keep up to date on news, events, and happenings in the Department of Chemistry & Chemical Biology. Connect with us on Facebook and follow @CornellChem on Twitter!

“What is...”

Professor Geoffrey Coates’s CHEM 6700 course was a question on the September 27th episode of Jeopardy!
Conventional wisdom has said that when molecules known as monomers band together to create a polymer chain, that creation takes place steadily as the chain forms, like spaghetti out of a pasta maker. But a Cornell research collaboration shows that’s just not the case.

In what one reviewer called a landmark study, a group led by Peng Chen, the Peter J.W. Debye Professor of Chemistry and Chemical Biology, has achieved several firsts while offering up a new theory on polymer growth. Using magnetic tweezers, a measurement technique never before used to study living polymerization, Chen and his group visualized growth at the single-polymer level, which also hadn’t been done before. Furthermore, the group’s study established that polymerization catalysis can be visualized at the single-molecule level under continuous turnover conditions.

This groundbreaking work revealed the continual formation and unraveling of conformational entanglements, nicknamed “hairballs,” that produce a step-wise extension pattern of polymer growth, as opposed to more continuous extension as was previously thought. Their findings are reported in “Single Polymer Growth Dynamics,” published Oct. 20 in Science. In addition to Chen, co-senior authors are Geoffrey Coates, the Tisch University Professor and associate chair of the Department of Chemistry and Chemical Biology, and Fernando Escobedo, the Marjorie L. Hart Professor of Engineering in the Smith School of Chemical and Biomolecular Engineering.

Lead authors are postdoctoral researcher Chunming Liu and doctoral student Kaori Kubo, both members of the Chen Group, as well as master’s student Endian Wang of the Escobedo Group.

Not only does the discovery of these “hairballs” appear to play a key role in determining the polymerization rates of individual polymers, this work could also help inform study of living bio-polymerization in cells.

In a typical polymerization reaction, a polymer chain grows from a catalyst continually to reach thousands of sub-units, but growth at the single-polymer level was not understood and hadn’t previously been observed.

“It was motivated by the long-existing knowledge that every polymer is different,” Chen said. “But people have never looked into it, and what I’ve been interested in is single-molecule studies.”

Using a so-called Grubbs catalyst, a robust complex known for its tolerance of manipulation in chemical experimentation, the group used magnetic tweezers measurements to monitor the growth of a polymer chain in real time. The measurement is done by anchoring one end of the growing polymer to a coverslip and the other to the catalyst, which is fitted with a tiny magnetic particle.

During polymerization, the insertion of new monomers leads to a lengthening of the polymer chain, and by tracking the position of the magnetic particle, the researchers tracked the growth of the polymer with nanometer-scale precision.

What they discovered is that, instead of steady extension growth, the polymer exhibits step-wise extension growth – the monomers do not add to the polymer extension during the growth period but instead appear to form conformational entanglements, or “hairballs.”

The periods between extension spurts are hundreds of seconds, and the spurts are up to thousands of nanometers, equivalent to thousands of monomers. Calculations showed that the polymer extension could not have grown in a steady fashion but instead in wait-and-jump steps. Simulations provided further insight into the forces that produce the hairballs and hold them together temporarily before they unravel suddenly.

“Most chemists would expect polymers to grow evenly from the active site, kind of like a string of spaghetti exiting a pasta machine,” Coates said. “What is unexpected, and therefore fascinating, is that this work shows the polymer lengthens erratically, which is attributed to the polymer chain being tangled as it leaves the active site, followed by bursts of disentanglement.”

Constant application of a magnetic force pulls the particle and stretches the polymer.
“In fact,” Escobedo said, “the model suggests that after each monomer is inserted, the chain gets twisted a little bit, as when turning the key of a wind-up toy. After many such ‘turns’ have taken place, a portion of the newly grown polymer would become entangled like a twisted telephone cord that then takes a while to untangle.”

New experiments, Chen said, will attempt to perturb the polymerization by either introducing new interactions or disrupting them – “to either make the hairball more stable or less stable,” he said.

This research is another example of the type of collaboration that sets Cornell apart from many institutions.

“This is a truly collaborative project between three scientists with vastly different skill sets – a theorist [Escobedo], a physical chemist [Chen] and a synthetic chemist [Coates],” Coates said.

“It seems almost impossible for this work to have been done with a subset of the expertise present.”

By Linda Glaser  |  Cornell Chronicle

General chemistry can be challenging, particularly for students whose high schools didn’t offer sufficient preparation. In response, the Department of Chemistry and Chemical Biology has incorporated recent pedagogical advances into a number of classes to teach students the quantitative reasoning necessary to succeed in the physical sciences.

Two general preparatory classes are open to all students at Cornell (CHEM 1070 and 1080) and are taught by Stephen Lee, professor of chemistry. Students work through flipped classes, peer-assisted workshops and scored practice exams; to complete the course, students are required to complete 80 percent of the given tasks.

The chemistry department has also incorporated active-learning techniques into its Pre-Freshman Preparatory (PSP) program, which provides disadvantaged students supplemental training in quantitative thinking to succeed in general chemistry courses. The PSP is based on intense problem-solving exercises and peer-led learning; a balance of problem types that encourage the development of physical intuition and general chemical reasoning have been found to provide the most effective outcomes. The PSP program is led by Lee and senior lecturer Steve Johnson, and grew from collaboration between the chemistry department and the Learning Strategies Center.

“Students participating in the PSP not only have greater success in freshman chemistry, but also show improvement in their other courses,” notes Brian Crane, the George W. and Grace L. Todd Professor in the Department of Chemistry and Chemical Biology and a Howard Hughes Medical Institute professor.

To encourage PSP students to pursue careers in research and medicine, the chemistry department has developed the Cornell-HHMI Accelerating Medical Progress through Scholarship (CHAMPS) program, supported by the Howard Hughes Medical Institute. The program’s first phase is a pre-sophomore organic/biochemistry preparatory course based on the PSP model, taught by senior lecturer Thomas Rutledge, combined with an initiation into laboratory work. In the program’s second phase, students conduct independent research in a mentored environment.

CHAMPS participants receive instruction in work practice, professional development, responsible conduct and the opportunity to hone their writing and presentation skills. An engaged course component encourages the students to lead scientific outreach efforts to K-12 schools in their home communities via remote learning platforms that can be readily disseminated through electronic media.

So far, nearly 40 students and 27 different Cornell research laboratories have participated in CHAMPS.

“Our overall goal is to nurture a group of well-trained, research-ready undergraduates who have a passion for science, the desire to engage in research careers and the ability to inspire peers to follow the same path,” says Crane.

CHAMPS has already proven its effectiveness: Crane says performance of CHAMPS students in sophomore organic chemistry has been exceptional. “More importantly, the students are taking additional steps to pursue careers in medicine and scientific research,” he says. “With demonstrated achievement at Cornell, the students are positioned to compete effectively for advancement in fields that will greatly benefit from an infusion of diverse perspectives and approaches.”
Group’s measuring tool probes solar-cell materials

BY TOM FLEISCHMAN | AS COMMUNICATIONS

Next-generation solar cells made from organic compounds hold great promise in meeting future energy needs, but researchers are still striving to gain a deep understanding of the materials involved – including the efficiency with which they convert light into mobile charge, known as photocapacitance.

A Cornell research group led by John Marohn, professor in the Department of Chemistry and Chemical Biology, has proposed a unique method for recording and measuring light-induced mobile charge – at nanoscale lengths and nanosecond time scales – at different areas in a heterogeneous solar-cell material.

One of the inefficiencies of organic solar-cell materials that Marohn and his group are addressing is recombination. When sunlight hits the material, it creates free charges (negatively charged electrons and positively charged holes) that get turned into electric current. But not all of those free charges escape the cell and turn into current; those that do not turn into current recombine, with the byproduct being heat.

The ability to “see” – or, more accurately, measure – charge generation and recombination following a burst of light was the group’s thrust behind developing pk-EFM. A conductive cantilever is placed near an organic semiconductor film; a voltage pulse is applied to the cantilever, while a carefully timed light pulse is applied to the sample.

The cantilever’s oscillation frequency is shifted slightly by the electrostatic interactions with the mobile charges in the sample. Those interactions result in a phase shift, or “phase kick” as the group calls it. This phase shift persists for a long time (nearly a second) and is therefore relatively easy to measure accurately.

The researchers study this phase shift as a function of the nanosecond time delay between the light pulses and voltage pulses. In this way, the researchers are able to indirectly infer what happened to charges on the nanosecond time scale without having to observe the charge directly, in real time.

“What we wanted was a way to see, in these tiny regions where different molecules are concentrated, how the charges recombine in the various regions of the sample,” Marohn said. “We’re trying to watch things that are both very fast and very small.”

The group’s work is trying to probe more deeply the photocapacitance of organic bulk materials that have previously been examined using time-resolved electric force microscopy. Future work will focus on getting even better spatial and temporal resolution in hopes of ultimately determining which combination of materials is optimal for efficient solar power.

“Solar cells work OK, and we don’t really understand how they work,” Marohn said. “It seems like, if you really understood how they worked, you could make them a lot better. And this is one way to try to figure that out.”

Funding for this work came from the National Science Foundation.
Yimon Aye, Assistant Professor

Chemistry professor honored with prestigious ACS award

BY YVETTE LISA NDLOVU  AS COMMUNICATIONS

Yimon Aye, a Howard Milstein faculty fellow and assistant professor of chemistry and chemical biology, has been honored by the Eastern New York Section of the American Chemical Society as the 2017 Buck-Whitney Award winner. Aye has been invited to give a talk at the awards ceremony Nov. 15 in Troy, N.Y.

The Buck-Whitney Award recognizes original work in pure or applied chemistry and outstanding contributions to chemistry. Previous awardees include Jack H. Freed, Cornell’s Frank and Robert Laughlin Professor of Chemistry, and Ahmed Zewail, winner of the 1999 Nobel Prize in Chemistry.

Aye and her lab associates have been working on unsolved biological problems targeting electrophile signaling and genome maintenance pathways, both at the fundamental and translational levels. Aye has received numerous honors for her contributions toward cancer research, including the Pershing Square Sohn Prize for Young investigators in Cancer Research in 2017, the Beckman Young Investigator Award, a National Science Foundation early career award in 2014, a National Institutes of Health Director’s New Innovator Award in 2014, a Sloan Foundation fellowship in 2016 and an Office of Naval Research Young Investigator award in 2017.

Aye received a B.S. degree in 2003 and a master’s degree in 2004 in chemistry from the University of Oxford and a Ph.D. in organic chemistry from Harvard University in 2009.

Co-founder of chemical ecology celebrates 90 years

BY YVETTE LISA NDLOVU  AS COMMUNICATIONS

Jerrold Meinwald, Emeritus Professor

Colleagues held a symposium in August to celebrate the birthday of Jerrold Meinwald, Goldwin Smith Professor of Chemistry Emeritus, who turned 90 in January. The symposium took place during the meeting of the International Society of Chemical Ecology in Kyoto, Japan.

Between 400-500 guests attended the symposium, which included talks by chemical ecology researchers and a chamber music recital by Meinwald (alto recorder), his wife, Charlotte Greenspan (harpsichord), along with two Kyoto friends, Toyoko Ogumi (flute) and Keiko Nagano (cello).

Meinwald is best known for his work on chemical ecology, a field he co-founded with his colleague and friend Thomas Eisner, the Jacob Gould Schurman Professor Emeritus of Chemical Ecology, who died in 2011. Meinwald was awarded the National Medal of Science at the White House in 2012, the nation’s highest honor for achievement in science and engineering.

Meinwald’s research has involved the isolation, identification, and synthesis of biologically active defensive and communicative compounds from insect and other arthropod sources, and identification of messenger molecules involved in plant/insect interactions.

A member of the National Academy of Sciences since 1969, the American Academy of Arts and Sciences (1970), and the American Philosophical Society (1987), Meinwald’s awards include the 2014 Nakanishi Prize of the Chemical Society of Japan; the 2013 Benjamin Franklin Medal in Chemistry and the 2008 Grand Prix of la Maison de la Chimie, among others.

Meinwald received his master’s (1950) and Ph.D. (1952) degrees from and Harvard University and his bachelor’s (1948) and Ph.B. (1947) from the University of Chicago.

Lancaster receives Sloan Fellowship

BY TOM FLEISCHMAN  AS COMMUNICATIONS

Kyle Lancaster, Assistant Professor

Assistant professor Kyle Lancaster has been named a recipient of an Alfred P. Sloan Foundation fellowship that supports early career faculty members’ original research and broad-based education related to science, technology and economic performance.

The Lancaster Group employs synthesis, biochemistry and a broad range of spectroscopic methods to explore small-molecule reactivity as mediated by transition metals. Recent work explored a biological mechanism that helps convert nitrogen-based fertilizer into nitrous oxide, an ozone-depleting greenhouse gas. The group published a paper on the topic in November 2016 in the Proceedings of the National Academy of Sciences.
Lin Group develops sustainable synthesis with electrochemistry

BY BLAINE FRIEDLANDER
CORNELL CHRONICLE

Give your medicine a jolt. By using a technique that combines electricity and chemistry, future pharmaceuticals – including many of the top prescribed medications in the United States – soon may be easily scaled up to be manufactured in a more sustainable way. This new Cornell research appears in Science Aug. 11.

Currently, making pharmaceuticals involves creating complex organic molecules that require several chemical steps and intense energy. The process also spawns copious amounts of environmentally harmful – and usually toxic – waste.

At the heart of many popular pharmaceuticals are vicinal diamines, which contain carbon-nitrogen chemical bonds, a bioactive foundation for the medicine. According to Song Lin, assistant professor of chemistry, many widely consumed therapeutic agents have these diamines, including prescription-strength flu medicines, penicillin and some anti-cancer drugs.

“The current process generates a lot of waste product to make this chemical bond. When you can create a product electrosynthetically, rather than chemically, it is much more straightforward and sustainable,” Lin said.

But the laborious tasks and chemical squander can go away. Lin and his team have developed a technique that creates vicinal diamines more easily and without the toxic waste. The process uses electricity and chemistry – electrochemistry – and then employs Earth-abundant manganese.

“The current process generates a lot of waste product to make this chemical bond. When you can create a product electrosynthetically, rather than chemically, it is much more straightforward and sustainable,” Lin said.

This process has not been used extensively, as electrochemistry and organic synthesis are not taught in colleges in an integrated way. The field is at the frontier, explained Lin. “Today, however, people generally are conducting interdisciplinary research,” he said. “Scientists realize that this is a powerful way to combine things in traditionally disparate fields.”

The technique also addresses chemists’ worry about the environment. “We are aiming to reduce pollution and to help our field become more sustainable, so we engage new technology for things like synthesizing pharmaceuticals,” said Lin. “We are focusing on how to get there.”

In addition to Lin as a senior author, “Metal-catalyzed Electrochemical Diazidation of Alkenes” was written by lead author Niankai Fu, graduate student Ambarneil Saha ‘18 and Aaron Loo ’19. Cornell laboratory startup money funded this research, and the National Science Foundation provides funding to Sauer.

Lin, along with Hector Abriñá, the Emile M. Chamot Professor of Chemistry, and Abe Stroock, the William C. Hooey Director and the Gordon L. Dibble ’50 Professor of Chemical and Biomolecular Engineering, were awarded a 2017 Academic Venture Fund grant at Cornell’s Atkinson Center for a Sustainable Future, for their research earlier this summer in creating cleaner, greener medicines.
Chemistry’s Coates elected to National Academy of Sciences

BY TOM FLEISCHMAN | CORNELL CHRONICLE

Geoffrey W. Coates, the Tisch University Professor in the Department of Chemistry Chemical Biology, is one of 84 new members elected to the National Academy of Sciences, the academy announced May 2.

Coates’ election brings to 60 the number of Cornell professors past and present – including Nobel laureates Hans Bethe (physics), Roald Hoffmann (chemistry) and Harold Varmus (Weill Cornell Medicine) – who have been elected to the academy since its inception in 1863.

Coates’ teaching and research interests involve science at the interface of organic, inorganic and materials chemistry. The broader impacts of his research include benign polymers and chemical synthesis, the use of renewable resources, and economical energy storage and conversion.

The Coates Research Group focuses on the development of new synthetic strategies for producing polymers of defined structure. This is accomplished through the development of new catalysts that control polymer composition, architecture, stereochemistry and molecular weight.

His group’s most recent work, “Combining Polyethylene and Polypropylene: Enhanced Performance with PE/iPP Multiblock Polymers,” was featured in the Feb. 24 issue of the journal Science.

Coates received his bachelor’s in chemistry from Wabash College in 1989, and his doctorate in organic chemistry from Stanford University in 1994. After postdoctoral studies at Caltech, he joined the Cornell faculty in 1997, and was appointed to the first Tisch professorship in 2008.

He teaches undergraduate organic chemistry as well as a graduate course on polymer chemistry.

An Alfred P. Sloan research fellow, Coates has received numerous awards from the American Chemical Society, including the A.C. Cope Scholar Award and the Affordable Green Chemistry Award, and was inducted to the American Academy of Science in 2011.

Ananth group’s recent work on singlet fission is ACS Central Science cover article

Ananth group’s recent work on singlet fission landed the cover of ACS Central Science. The article, entitled “A Direct Mechanism of Ultrafast Intramolecular Singlet Fission in Pentacene Dimers”, can be found here:

http://pubs.acs.org/doi/abs/10.1021/acscentsci.6b00063

For more information about the research in the Ananth laboratory, please visit the Ananth Group Website.
An iodabenzene story

The name immediately evoked benzene, an icon of organic chemistry. Chemists have been studying benzene and its relatives for over 150 years. Thomas Pynchon, Cornell graduate, his book Gravity’s Rainbow can tell you a little more of the remarkable story of benzene. Iodabenzene, which would be similar to benzene but with a slightly different make-up, just one carbon and hydrogen in benzene substituted by an iodine (ergo the ioda- moniker), nothing to do with Star Wars. Iodabenzene did not and does not (yet) exist.

But could it?

I said to Koser, “That molecule is in trouble.” Koser knew why I said what I did, and I knew Koser knew I knew. Because we shared a common background. For nearly 90 years we have been aware that in benzene, having 6 so-called $n$ electrons – which describe a particular kind of bond between atoms, nothing to eat – that this is good and having two more $n$ electrons past the six is bad. And we knew both of us that iodabenzene would have 8 $n$ electrons.

“We’ll look at it,” I told Koser.

Trouble, iodabenzene’s kind of trouble, is a challenge. It took a while. Finally, eight years ago a talented young Jordanian chemist, Abdel Rawashdeh, came to Cornell. Using a computer to do his intensive calculations, he found out something important about the shape of the hypothetical iodabenzene; this molecule did not want to be flat. “Want” that, of course, is an anthropomorphic way to talk about molecules. We started to call the structure that emerged for the molecule a “bird,” because that’s the way it looked.

Now, professional gatekeepers – we have them too, the editors of our journals – they didn’t like either term, but I think anthropomorphisms are a good way to describe life.

Abdel went back to Yarmouk University in Jordan. But the job was not done.

But I am patient. In 2016 a new postdoctoral associate from India, Priyakumari, who calls herself Priya, joined the group, and took on the study. We felt that iodabenzene went into the bird shape to avoid the trouble the 8 $n$ electrons gave it. Of course we were not interested in gaging the misery of the molecule, to which detailed calculations testified -- that would be somewhere between boring and sadistic. But iodabenzene’s trouble with its $n$ electrons made us think of a class of molecules known from the 19th century, called Meisenheimer complexes. And we knew that a strategy exists, has existed for many years, for stabilizing these Meisenheimer complexes, a way to substitute some atoms in the molecule. Computer calculations confirmed our intuition that this strategy also worked for iodabenzene.

What does this small chemical story have to do with being human? To be human is to try to understand.

Simulations – that’s what our computer was doing for us – that’s not understanding.

Yes, human ingenuity and understanding built those PC cores on which we compute. And there is still more human creativity in the software we share.

But numbers do not constitute understanding. It was Gerald Koser and I who asked the question, “What is wrong with this molecule?” It was Abdel and Priya and I who made the computers part of our humanity, as we sought an answer, who formed a conversation with the human imagination out of those numbers flitting across a display. We reasoned, in a contemporary way, a state of the art way, using quantum mechanics, buy still in ways rooted in the past (remember those 19th century Meisenheimer complexes?). We reasoned in words and images and chemical structures. And, inspired by likenesses—chemical metaphors, really – we crafted a strategy for changing iodabenzene from just an unhappy molecule to one that our friends in Akron or Rostov-on-Don or anywhere in the world just might make. Coming up with that strategy, that was being quintessentially human.
Baskin, Chang win Beckman Young Investigator award

Assistant professors Jeremy Baskin, from the College of Arts and Sciences, and Pamela Chang, from the College of Veterinary Medicine, are among eight assistant professors across the nation to be named a Beckman Young Investigator, a prize is given to promising young faculty members in the early stages of their academic careers in the chemical and life sciences.

The main purpose of the award, given by the Arnold and Mabel Beckman Foundation, is to foster the invention of methods, instruments and materials that will open new avenues of research in science.

“We are excited to support these amazing researchers,” said Anne Hultgren, executive director of the Beckman Foundation. “The foundation is committed to helping launch our next generation of talented scientists by giving them the funding and flexibility they need to pursue novel areas of study that have the potential for revolutionary breakthroughs.”

Baskin is in the Department of Chemistry and Chemical Biology; Chang is in the Department of Microbiology and Immunology.

The Baskin Lab works on chemical approaches to probe the cell biology of diverse classes of lipids (fats), with a major focus on developing new molecular imaging methods. The lab combines chemical biology, biochemistry and cell biology to develop innovative methods for imaging and probing various classes of lipids in vivo. Lipids are a diverse group of biological molecules that act as energy stores – components of membranes and initiators of signaling pathways that allow cells to coordinate actions and communicate with one another. These molecules have proven notoriously challenging to study using traditional genetic and biochemical approaches.

In his proposal to the Beckman Foundation, Baskin describes a chemical technology to create individual lipids on demand within live cells and, thus, control the content of biological membranes. This would allow for imaging and studying the effects of individual lipids on cellular behaviors.

The Chang Lab conducts research aimed at understanding how the host immune system is regulated by the gut microbiota through secretion of small molecule metabolites. Inflammation is a physiological process in infection and tissue repair after injury. Uncontrolled, however, chronic inflammation caused by overactivation of immune cells is a symptom of many diseases. Because current anti-inflammatory drugs are given systemically and have many negative side effects, there is great demand for next-generation technologies to locally inhibit activation of the immune system.

Chang’s lab aims to develop precision chemical tools to inhibit local inflammation by modulating the functions of target populations of immune cells and apply these tools to study fundamental biological mechanisms of inflammatory pathways and control the immune response in therapeutic settings.

The Beckman Young Investigator award carries with it funding for four years, contingent upon demonstrated progress after the second year. Baskin and Chang each will receive $750,000 over the course of the grant to support their research.

Chemist honored with ACS symposium

The American Chemical Society hosted a symposium at its annual meeting in August in celebration of the 90th birthday of Ben Widom, emeritus professor of chemistry and chemical biology.

“Liquid Theory: In Honor of Ben Widom’s 90th Birthday,” was organized by Dor Ben-Amotz, professor at Purdue University; Kenichiro Koga, professor at Okayama University; and Cornell Professor Roger Loring.

Widom earned a bachelor’s degree from Columbia and his doctoral degree from Cornell.

A faculty member for more than half a century, Widom was also honored in 2015 with a special issue of the journal Molecular Physics. In the issue’s foreword, journal editor Jean-Pierre Hansen and University of Oxford chemist Sir John Rowlinson call Widom “one of the most respected and influential figures in theoretical chemistry and statistical mechanics, worldwide.”

Widom is perhaps best known for his work toward understanding the properties of substances near the critical point – the point at which two phases of the substance (water and water vapor, for example) lose their distinguishing features and behave as one, or at a tricritical point, where three previously distinct phases lose their separate identities.

The Beckman Young Investigator award carries with it funding for four years, contingent upon demonstrated progress after the second year. Baskin and Chang each will receive $750,000 over the course of the grant to support their research.
Bacterial mechanism converts nitrogen to greenhouse gas

BY BLAINE FRIEDLANDER | CORNELL CHRONICLE

Cornell researchers have discovered a biological mechanism that helps convert nitrogen-based fertilizer into nitrous oxide, an ozone-depleting greenhouse gas. The paper was published online Nov. 17, 2016 in the Proceedings of the National Academy of Sciences.

“The first key to plugging a leak is finding the leak,” said Kyle Lancaster, assistant professor of chemistry and chemical biology, and senior author on the research. “We now know the key to the leak and what’s leading to it. Nitrous oxide is becoming quite significant in the atmosphere, as there has been a 120 percent increase of nitrous oxide in our atmosphere since pre-industrial times.”

Lancaster, along with postdoctoral researcher Jonathan D. Caranto and chemistry doctoral candidate Avery C. Vilbert, showed that an enzyme made by the ammonia-oxidizing bacterium Nitrosomonas europaea, cytochrome P460, produces nitrous oxide after the organism turns ammonia into an intermediate metabolite called hydroxylamine.

N. europaea and similar “ammonia-oxidizing bacteria” use hydroxylamine as their fuel source, but too much hydroxylamine can be harmful – and the resulting production of nitrous oxide is a chemical coping strategy.

Lancaster and his colleagues hypothesize that when ammonia-oxidizing bacteria are exposed to high levels of nitrogen compounds, such as in crop fields or wastewater treatment plants, then nitrous oxide production via cytochrome P460 will ramp up.

In the atmosphere, greenhouse gases are a soup of many species, and Lancaster explained that nitrous oxide has 300 times the potency of carbon dioxide. “That’s a staggering number,” he said. “Nitrous oxide is a really nasty agent to be releasing on a global scale.”

Lancaster added that nitrous oxide is photochemically reactive and can form free radicals – ozone-depleting agents – which aggravates the issue of blanketing Earth’s atmosphere with more gas and raising the globe’s temperature. “In addition to its role as a greenhouse gas cloak, it’s removing our protective shield,” Lancaster said.

The United States is among the world leaders in importing nitrogen fertilizer, according to the U.S. Department of Agriculture’s Economic Research Service. The Food and Agriculture Organization of the United Nations noted that the world’s nitrogen fertilizer demand was projected to be 116 million tons for this past agricultural season.

“For the world, I realize that we are trying to feed more people and that means more fertilizer – and that means more nitrous oxide,” said Lancaster, who noted that about 30 percent of nitrous oxide emissions come from agriculture and its accompanying land use.

To reduce the negative impact of nitrogen, farmers already use nitrification inhibitors.

Said Lancaster: “While it will be challenging to develop ways to stop this process, now we have pinpointed one biochemical step leading to nitrous oxide production.

Future work may lead to inhibitors, molecules that can deactivate or neutralize this bacterial enzyme. Alternatively, we may just use this new information to develop better strategies for nitrogen management.”

The Department of Energy Office of Science and the National Institutes of Health supported the research.

Kyle Lancaster, assistant professor of chemistry and chemical biology, and Avery Vilbert examine a thin vial of cytochrome P460 that helps to convert agricultural nitrogen (fertilizer) into nitrous oxide, an ozone-depleting greenhouse gas.

Skibinski awarded Nottingham Prize

Erik S. Skibinski, a member of the Hines group, has been awarded the 2017 Wayne B. Nottingham Prize in surface science for his investigations of the chemistry and photochemistry of metal oxide surfaces. Erik developed techniques that use solution-phase chemistry to produce controlled organic monolayers with the near-atomic perfection necessary for STM investigations of photochemical surface reactions. The Nottingham Prize has been given annually since 1966 and recognizes the most outstanding contribution to the Physical Electronics Conference based on a Ph. D. thesis.
Aye group discovers avenue for precision cancer treatment

BY TOM FLEISCHMAN | CORNELL CHRONICLE

One of the goals of personalized medicine is to be able to determine which treatment would work best by sequencing a patient’s genome. New research from the lab of Yimon Aye, assistant professor of chemistry and chemical biology, could help make that approach a reality.

Using her group’s novel chemical procedure dubbed “T-REX,” along with a patent-pending targeting molecule also developed in her lab, Aye and her group have uncovered interesting facets of several well-known cancer-cell mutations that, if present in a patient, could inform treatment options and potentially produce more favorable outcomes.

“People wonder why certain drugs are more efficient in one individual over another,” said Aye, a Milstein Sesquicentennial Fellow in the College of Arts and Sciences who also has a joint appointment in the Department of Biochemistry at Weill Cornell Medicine.

“Our discovery gives us a foundation to think about and design inhibitors that will ... be much more effective in the patients carrying certain mutations.”

The Aye Lab has published two related papers on this discovery in the last couple of months, both in Cell Chemical Biology.

“Privileged Electrophile Sensors: A Resource for Covalent Drug Development” was published online June 22; “β-TrCP1 Is a Vacillatory Regulator of Wnt Signaling” was published online July 20.

The first paper explains how reduction-oxidation, or redox, signaling – which is commonplace inside cells – affects the activity of specific enzymes, and how certain enzymes’ redox-specific processes could be harnessed for targeted drug design.

Research for the second paper started to test that theory. To determine which signals are affecting the response of a particular protein, the group used its T-REX procedure coupled with a widely used strategy to deplete the cell of a specific protein of interest.

One challenge is that multiple variations, or isoforms, of the same protein can all catalyze the same cellular function, “but the nuances of biology rest in how individual isoforms are regulated,” Aye said.

“Some may be important in only certain types of tumors, or certain types of cells, so being able to discriminate one isoform over the other is important,” she said.

The group’s first key finding: The “cross-talk,” or interaction back and forth, between cell signaling pathways is regulated depending on the concentration of a certain transcription factor (Nrf2), a fact that isn’t clear unless you are able to selectively stimulate Nrf2 signaling, a method Aye pioneered.

The second, and perhaps more interesting in terms of disease: A key mutation of cancer cells on the N-terminus – the start of a protein chain, which often contains key signaling information – would make them more susceptible to certain targeted therapeutics than those without the mutation.

“What we’ve discovered as a strategy is a means to target this pathway in the cancer cells that carry selective mutations on this domain [the N terminus],” Aye said. “Potentially, patients can be genotyped to see if they carry these mutations, and they should respond much better to small molecules that activate antioxidant response.”

Aye said understanding the many complexities of oncogenesis and cell signaling is crucial to developing better therapies for cancer and other diseases. “We could design much more selective therapeutics by understanding the underlying cross-talk,” she said.

Marcus J.C. Long, a postdoctoral researcher in the Aye Lab, was lead author on the first paper and co-lead with former postdoc Hong-Yu Lin on the second. Other contributors included current postdoc Yi Zhao, doctoral students Saba Parvez and Jesse Poganik, and undergraduate chemistry and biology major Paul Huang ‘18. All are members of the Aye Lab and the Department of Chemistry and Chemical Biology.

This work was supported by grants from the National Science Foundation, the National Institutes of Health, the Sloan Fellowship, the Beckman Foundation and the Office of Naval Research.
The American Chemical Society Cornell Section Undergraduate Research Award for seniors was awarded to Michael Disare, Samuel Newman-Stonebreaker, Julie Urgiles, Yuchen Sun and Christian Gomez.

The George C. Caldwell Prize was awarded to Shivansh Chawla and Sophia Lai.

The Leo and Berdie Mandelkern Prize for seniors was awarded to Alisa Lee and Vanha Pham.

The Merck Index Award for seniors was awarded to Jane Vecca.

The Harold Adlard Lovenberg Prize for juniors was awarded to Ilana Kotliar and James Sun.

The Tunis Wentink Prize for graduate students was awarded to Saba Parvez, Erik Skibinski, and Richard Walroth.

The Howard Neal Wachter Memorial Prize for graduate students was awarded to Matthew Church and William DeBenedetti.

The Covestro Teaching Excellence Award for graduate students was awarded to Aran Hubbell, Ting-Wei Lin, Brian Peterson, Sean Majer, and Alexandra Van Hall-Beauvais.

The Frank L. and Lynnet Douglas Fellowship for Underrepresented Minority Undergraduates was awarded to Jazmin Aguilar-Romero, Matthew Carter, and Lining Zheng.

The Gerald A. Hill and Kathleen Holmes Hill Fellowship for Undergraduate Summer Research was awarded to Brendan Murphy.

The Robert W. Work Fellowship for Undergraduate Summer Research was awarded to Aaron Loo, Devika Pokhriyal, and James Sun.

The J. Emery Morris Fellowship for Undergraduate Summer Research was awarded to Paul Huang, Cathy Ly, Amith Punyala, and Zach Zheng.

The Bauer Scholarship Award was awarded to Spencer Heins, Michael Lynch, Kyle Mack, Maria Sanford, and Avery Vilbert.

The Howard Neal Wachter Memorial Prize for graduate students was awarded to Matthew Church and William DeBenedetti.

The Hypercube Scholar Award was awarded to Jonathan Wong.

The Outstanding Senior Organic Chemistry Student Award was awarded to Christian Gomez.

The Darryl H. Wu Memorial Prize was awarded to Wendy Cao and Anna Overhols.
Intrigued by chemistry

BY ADITYA BHAROSA ’20  CORNELL RESEARCH

Ashley Vincent ’17 admits that she used to score average grades in chemistry while in high school. “The reason why I chose chemistry as a major is slightly unconventional. Most students major in their strongest subject areas, but chemistry wasn’t really one of my best subjects in high school. I applied to colleges as a prospective chemistry major because of my interest in the field, despite knowing that I’d probably have to make a greater effort than others to develop my skills.”

During her freshman year at Cornell, Vincent joined Alpha Chi Sigma, a century-old chemistry fraternity. “I love the interactions we have during our meetings. Our members are all majoring in fields related to chemistry, and the engagement that I’ve had during my time in the fraternity has been priceless.” These engagements include expositions at the Ithaca Science Center as well as access to professional networking sessions and research opportunities across the Cornell community.

Analyzing Enzymes

A fraternity member upon graduating in 2014 contacted Vincent, informing her of the vacancy she’d left at Kyle Lancaster’s lab, Chemistry. Vincent applied for the position and began working in the summer of her sophomore year.

“The initial learning curve of the research process is pretty steep, and I thought it’d be better to start in the summer, when I had more time to learn the ropes. Of course, it became an easier process from then on.”

Modern scientific research is increasingly highlighting the presence of archaea (or archaeabacteria, bacteria-like organisms but with different molecular structures) as the dominant nitrifying organisms in both marine and terrestrial environments. Their biochemistry, however, is largely unknown. The Lancaster lab is working to provide an updated body of knowledge about biological ammonia oxidation, which can be applied across different scientific fields.

Working with graduate chemical biologists in the biochemistry section of Lancaster’s lab, Vincent studies the metabolism used by nitrifying microbes to extract energy from ammonia. Vincent’s particular enzyme is involved in oxidation of hydroxylamine, a key energy-rich intermediate produced by these organisms.

Ideally the lab would like to analyze each enzyme present within the oxidation cycle in isolation. However, Vincent says that it’s an extremely difficult task to spectroscopically study each enzyme in nitrifying microbes. “Frequent complications occur, relating to incompatible heme types and the loss of signals from the active sites, so we have to look at creative solutions to execute the process.”

Vincent and her team members therefore study similar enzymes that are present outside the cycle. They study cyt P460, an enzyme similar to HAO and analyze the mechanism of HAO oxidation through the enzyme.

While Vincent acknowledges that the quality of research is dependent on how much time one puts in, she also points out that there are many uncontrollable variables present in the entire process. “Initially, all our research experiments involve trial and error. We might begin working with an enzyme only to then realize it’s unstable and impossible to work with. But there’s no way of knowing this beforehand.”

A Research Experience with Many Benefits

Interestingly though, the unpredictability also comprises her favorite aspect of the process. “I’m always open to learning new things, not just in chemistry, but also from other subject areas like biochemistry and physics. Understanding how things work on a fundamental level fascinates me.”

Through the course of the two years she’s spent at the Lancaster lab, Vincent has developed close friendships with several researchers. On Tuesdays each subgroup meets for lunch, and every group member presents a slideshow, explaining their weekly progress. “It’s a great activity in terms of the interaction regarding research, and it helps me catch up with my group members, too.” As for assistance with her research, the first person Vincent usually approaches is postdoctoral associate Jonathan Caranto. Vincent describes him as a diligent researcher, frequently the first researcher to enter the lab in the morning. “He’s in charge of introducing the new researchers in the biochemistry section to our methods, so I acquired most of my specific research skills from him. He’s great with providing feedback and direction on my research.”

Vincent says that juggling her extensive research commitments with courses is often an arduous task, but she appreciates the depth of engagement and support provided by Lancaster. She remembers one particular semester during her junior year when she began wondering if she could keep up with her work schedule. “I was taking several honors classes and had four credits worth of research on top of that. Professor Lancaster was really the one who’d remind me to relax, and I’ve found his advice useful beyond the research process.”

When she looks back on the college application process now, Vincent is certain she made the right choice. “In the end, I was choosing between Amherst and Cornell. Amherst is a great school, but for a research-oriented subject like chemistry, Cornell seemed a much better fit.” She’s always reminded of the quality of the faculty at Cornell. “We tend to take for granted the research opportunities and the fact that we’ve got daily access to a Nobel laureate and so many other great researchers. It still amazes me.”

After graduating, Vincent plans to take a gap year during which she is looking to work in the medical sector. Following her gap year, she will pursue a medical degree.
Melissa Hines, professor of chemistry in the College of Arts and Sciences, guided the Cornell Center for Materials Research (CCMR) for two terms as director and shepherded the center through two critical funding cycles from the National Science Foundation, including its most recent renewal, announced last month.

And in September, after 12 successful years at CCMR’s helm, she turned the reins over to Frank Wise, the Samuel B. Eckert Professor of Engineering in the Department of Applied and Engineering Physics (AEP).

Wise is the 10th director of the CCMR, which was founded in 1960 as the Cornell Materials Science Center. He said his short-term goal is to learn about every aspect of the highly respected center – and “not mess anything up,” he added with a smile.

“Frank Wise is an excellent choice,” said Hines, who took the position in 2005 from Francis DiSalvo, the J.A. Newman Professor Emeritus of Chemistry and Chemical Biology. Hines’ tenure was the longest in CCMR history, though two other directors – Herbert Johnson (1974-1984) and John Silcox (1989-1997) – also served multiple terms.

“Frank has a deep understanding of materials research as well as extensive administrative experience,” said Hines, noting that Wise served as director of AEP from 2007 to 2011 and has served on the CCMR executive committee.

Wise said one of the things he likes most about the CCMR is that it fosters the type of research – collaborative work, across campus and disciplines – for which Cornell is known.

“It specifically supports interdisciplinary research – the kinds of things that no individual research group could do alone,” he said. “In addition to faculty producing world-class science, it has contributed enormously to materials infrastructure at Cornell. This includes the strong culture of cooperation and collaboration on campus.”

Hines this year helped the center secure a six-year, $23.2 million funding extension from the National Science Foundation (NSF), a 26 percent increase over its 2011 NSF grant.

“I am grateful for the tremendous dedication of Melissa Hines, who has masterfully guided the CCMR over the past 12 years,” said Emmanuel Giannelis, vice provost for research and vice president for technology transfer, intellectual property and research policy.

“The center has been remarkably successful in producing world-leading research, while simultaneously evolving to go in new research directions,” Wise said. “The latter is always a challenge and is viewed as critical by the NSF. Melissa did a brilliant job leading her staff and faculty in the center.”

The CCMR, funded by the NSF and New York state, is an interdisciplinary research center whose mission is to advance, explore and exploit the forefront of the science and engineering of advanced materials. This objective is pursued through fundamental, experimental and theoretical studies.

CCMR’s mission includes three other critical components: educational outreach to teachers and students; industrial outreach and knowledge transfer; and the operation of shared instrumentation in support of materials research, on and off campus.