Nanoseparations by Vector Chromatography

By Mary Spiro

Around Maryland Hall, Assistant Professor German Drazer has gained something of a reputation as "that guy with the enormous Lego contraption in his lab." Mounted vertically to a rotating wheel in his first-floor laboratory, it consists of thousands of Lego pegs arranged on Lego boards sandwiched between two clear Plexiglas sheets. Drazer fills the apparatus with a mixture of water, glycerol, and small plastic beads to demonstrate fundamentals of his research on how particles separate and move through microdevices.

In collaboration with Assistant Professor Joelle Frechette, he uses the toy building bricks to demonstrate the behavior of particles, cells, and macromolecules in environments too small to be seen. "If you know one single parameter, in this case the measure of the asymmetry in the motion of a plastic bead around a single Lego peg, you can predict the path that particles will take in the entire array at any forcing angle," he says.

The media jumped on Drazer and Frechette's novel way to explain separation science, and stories about how he used Legos to describe nanoscale forces appeared in *WIRED* and *Fast Company* magazines and on the National Science Foundation website. And while Drazer admits that his method of explaining microfluids research was fun, he also stresses that the significance of the research is not a game.

With this understanding of vector chromatography, Drazer says, one can predict how different types of particles might separate. This is important to understanding the field of microfluidics—used in the development of lab-on-a-chip technology. Another example: separating diseased cells from healthy ones. This is critically important, for example, in detecting and isolating circulating tumor cells.

In his investigations of separation science and forces that influence the behavior of particles at the nano- and microscale, Drazer is studying vector chromatography to sort cells with doctoral student Jorge Bernate. The pair has developed a microfluidic device capable of sorting particles based on their effective mass. They plan to use the device to isolate magnetically labeled circulating cancer cells from other blood components.

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Message from the Chair

Dear JHU ChemBE Friends and Alumni,

The past year has been tremendous for the Johns Hopkins ChemBE department, marked by the terrific success of our faculty and students in areas ranging from awards and research funding to publications and other university activities. I am happy to share with you some of these achievements and let you know what lies ahead.

There has been much recent media attention on how best to measure faculty productivity at universities. Because intellectual and educational productivity is difficult to quantify and open to interpretation, these measures have, at times, been quite controversial. Nevertheless, I am happy to report that according to many of the performance measures being proposed, our department has outstanding scores. Our accomplishments are even more impressive given that we have had the nation’s highest percentage of assistant professors in our field.

Despite our young composition, each ChemBE faculty averaged more than six peer-reviewed papers per year since 2008, and annual research expenditures per faculty have nearly tripled in five years. In FY10, per-faculty research expenditures were in excess of $800,000 and are on a trajectory to remain strong. Another important outcome of this success: Since 2006, 14 ChemBE doctoral students and postdoctoral fellows have secured tenure-track faculty appointments at leading national and international universities, including Georgia Tech, MIT, Rice University, University of Florida, and Indian Institutes of Technology. Among last year’s graduating seniors, 40 percent continued with graduate studies at schools including MIT, Rice University, U Penn, and Cornell; 20 percent enrolled in professional schools; and the remainder are employed in a variety of fields.

Our graduate program has grown to 83 PhD and 27 MSE students and 23 postdoctoral fellows while our undergraduate enrollment has remained at 300 for the past five years. This fall, we welcomed 30 new graduate and 75 undergraduate students who were selected from a record-breaking pool of applicants.

Also this fall we welcomed two assistant professors, Rebecca Schulman and Zachary Gagnon, who strengthen our research efforts in nanobiotechnology. Given all these factors, it is clear that ChemBE is poised to excel in the years to come while remaining focused on our core mission: developing leaders who will explore uncharted engineering, scientific, and medical frontiers for the benefit of society.

In closing, I would like to congratulate my colleagues on their recent successes and express my sincere appreciation to our students, alumni, and friends whose support is essential to our success.

We look forward to another exciting year in ChemBE.

Best wishes,

Konstantinos Konstantopoulos

New Faculty: Zachary Gagnon Explores Cell Stress

By Mary Spiro

Just like humans, cells experience a plethora of stressors. Assistant Professor Zachary Gagnon, who joined the ChemBE department this summer, aims to find out exactly how cells respond when exposed simultaneously to a variety of stressors.

“Many groups study one type of cellular stress factor at a time, such as chemical gradients, electric fields, or shear forces,” Gagnon says. “In reality, the cell is experiencing many forces at the same time. I want to take that to the next level through a new assay that puts multiple stressors on top of each other to see how that affects the output of the cell. If we can understand how cells respond to multiple inputs, we can better understand what pathways to target to stop the spread of cancer cells, for example.”

Gagnon uses microfluidics and dielectrophoresis to sort and manipulate different cell types. “Dielectrophoresis works by creating a voltage difference between electrodes, and the electric field exerts a force on particles or cells,” Gagnon explains. “You can change the way the voltage polarizes the electrodes to get the particles to move.”

That force can be used to pump fluids, manipulate particles, or concentrate them into a very small space, such as within the compartments of a microfluidic device.

After earning his PhD in chemical engineering at the University of Notre Dame, Gagnon worked with his advisor there, Hsueh-Chia Chang, using particles as biosensors that bind a specific DNA sequence. “When the particles bind, it changes the way they move in the electric field, and that can let you know whether your gene of interest is in solution,” Gagnon says.

He also worked as an applications engineer at Millipore, where he designed, built, and performed fluid mechanics experiments—all skills he then used as a postdoc with Peter Devreotes, a professor of cell biology at Johns Hopkins School of Medicine. There, Gagnon used electrical forces as part of an electrotaxis and chemotaxis cell migration assay inside a microfluidic device.

Now Gagnon will use these tools to study cell migration, such as cells in response to growth factor cues, electric fields, shear stress, or chemotactic gradients.

Gagnon came to Hopkins because of the opportunities to collaborate with researchers at the medical school, including in the Devreotes lab (where he has access to cell lines that would be difficult to maintain on his own) and with Douglas Robinson, who holds a primary
Usually DNA serves as a kind of biological source code of genetic information. But for Rebecca Schulman, who joined the ChemBE department this fall, DNA is also a versatile building material.

“The original dream of nanotechnology was to be able to control matter at the molecular scale,” Schulman says, “and DNA possesses many properties that make it an ideal nanoscale building material.”

A strand of the DNA double helix measures just two to three nanometers across and can be synthesized up to nearly 100 base pairs in length. Schulman explains that the strand also possesses “sticky ends” of complementary sequences that allow it to connect to other strands. By assembling several DNA strands into branched structures, Schulman says the molecule can be used to build complex patterns, networks and crystal structures, from which more complex structures can be fabricated.

“A single-stranded DNA molecule is one-dimensional,” she says. “By hybridizing two strands of DNA together, one may build in two and then three dimensions. Because DNA behaves very predictably, it allows us to build extremely complex materials not possible with other materials, such as proteins. We can design a self-assembly process by designing DNA sequences and having those sequences made.”

The physical structure of DNA also can impart information to the materials it is used to build. Schulman compares this to having a compiler take source code and build it into a language that a machine would understand.

“The folding and assembly of DNA molecules is surprisingly complex, and can act as a computer program,” she says. “We can think of designing molecules that assemble complex structures in much the same way we think about designing computer programs.”

As an example, Schulman describes a DNA-based structure capable of executing a simple counting program. “The dynamics of these puzzle pieces tend to be very complicated, so rules by which we can manage them come from computer science.”

Applying principles of computer science to engineering problems comes naturally for Schulman, who earned undergraduate degrees in mathematics and computer science from the Massachusetts Institute of Technology. She then applied some of these ideas in her doctoral dissertation on self-replication and evolution of DNA crystals at the California Institute of Technology. Most recently, she was a Miller Fellow in the department of physics at the University of California, Berkeley, where she pursued these ideas further.

“Biology has figured out how to put molecules together in very complicated ways and surprising patterns, such as the ribosome or a virus capsid,” Schulman says. “We, as engineers, are not quite to the state where we can build such things. So this is really a problem for chemical engineers.”

Schulman is originally from the Baltimore-Washington area and is happy to be closer to her family and to have the chance to work with Hopkins colleagues like Jeff Gray, associate professor in ChemBE, who uses computer simulations to predict how proteins attach and interact with one another.

“DNA can be used as a scaffold upon which other materials may be arranged,” Schulman says. “What I hope that I have done is applied things that I learned as an undergraduate in computer science and brought some unique insight into this problem. At the end of the day, we are using techniques from computer science, but we are building molecules.”
Faculty Awards

Dilip Asthagiri, assistant professor, co-authored “Thermodynamics of Water Modeled with Ab Initio Simulations” in The Journal of Chemical Physics, a top-downloaded paper published in October of 2010. In addition, he won a Kenan Award for his educational endeavors in the undergraduate course Data Analysis and Modeling.

Michael Bevan, associate professor, received a 2010 Editor’s Choice Award from The Journal of Chemical Physics for his work developing new methods to measure and model colloidal interactions. His recent papers addressed topics including measurements of protein interactions, three-dimensional tracking of nanoparticles, and the development of dynamic models for feedback control of colloidal assembly processes. His work is currently funded by AFOSR, NIST, and three NSF grants.

Joelle Frechette, assistant professor, is one of only 21 recipients of the 2011 Office of Naval Research (ONR) Young Investigator Award. The award was given for her proposal, "Understanding the Role of Hydrodynamic Forces on Wet Adhesion."

Sharon Gerecht, assistant professor, received an NSF CAREER Award in 2011 to investigate microenvironmental cues that are essential for vascular differentiation. In addition, the National Heart, Lung and Blood Institute recently awarded her an RO1 grant to study three-dimensional vascular network formation.

David Gracias, associate professor, received an Alexander von Humboldt Fellowship for sabbatical research in Germany last spring. His group was awarded an NSF grant to develop biosensing tools and materials and an American Heart Association grant, with Dr. Lewis Romer of the Johns Hopkins Children’s Center, to study oxygen regulation of three-dimensional pulmonary capillary morphogenesis. Gracias’ laboratory publications were featured on the cover of Angewandte Chemie, Advanced Functional Materials, and Small. Gracias was a plenary bionano-technology session speaker at the recent AIChE national meeting and delivered a lecture on self-assembly at the Kavli Frontiers of Science Symposium in Shenzhen, China.

Jeffrey Gray, associate professor, was named the F. Stuart Hodgson Faculty Scholar. Research from his lab was featured on the cover of the April 2011 Journal of Dental Research. Gray was awarded a Kenan Grant to incorporate Peer-Led Team (PILOT) approaches into the Process Analysis course this fall. Undergraduates from Gray’s lab have secured Graduate Research Fellowships from the National Science Foundation for three years in a row.

Konstantinos Konstantopoulos, professor and chair, was named chair of the Bioengineering Technology and Surgical Sciences (BTSS) study section at NIH effective July 1, 2011. He was selected to receive the 2011 Robert H. Pond, Sr., Excellence in Teaching Award.

Marc Ostermeier, professor, was promoted to full professor and awarded a three-year $675K grant from the NSF Division of Environmental Biology to use synthetic biology tools to address fundamental questions in evolution. This fall, Ostermeier was named vice chair of the department.

Denis Wirtz, professor, was named the AIChE Area 15 d/e Plenary Award Winner for 2011.

Graduate Awards

Colin Paul from the Konstantopoulos lab received a National Science Foundation Graduate Research Fellowship. Honorable Mentions were awarded to Barrett Steinberg and Nathan Nicholas of the Ostermeier lab and Christian Pick of the Frechette lab.

Donny Hanjaya Putra and Stephanie Fraley, PhD ’11, are 2011 Siebel Scholars.

Sravanti Kusuma was awarded an American Heart Association Pre-doctoral Fellowship.

Purushottam Dixit, PhD ’11, won a 2010 Peter Salamon Young Scientist Award.

Stephanie Fraley, PhD ’11, received an NSF/ASEE Engineering Innovations Fellowship.

Rohini Gupta won an Alan Gent Distinguished Paper Award and a Peebles Award, both from the Adhesion Society.

Mustapha Jamal has been awarded a Ford Foundation Fellowship.

Undergraduate Awards

Kelly Schwarz ’12 received the 2011 Genentech Process Research & Development (PR&D) Outstanding Student Award.

Marianna Sayeg ’12 from Jeff Gray’s lab, won first place in her section for her poster at the recent AIChE conference. Stephen Zhao ’12 of Sharon Gerch’s lab, won third place in his section.

Skyler Stern and Vivek Bose received Elenora Streub Muly Awards recognizing their contributions in the labs of Associate Professor Michael Bevan, and Assistant Professor Sharon Gerch.

Boomsong Uranukul ’12, Moon Young “Liza” Lee ’12, Kelly Schwarz ’12, and Alvin Chua ’12 received American Institute of Chemical Engineers Awards for Scholastic Achievement.

Joanna Tsao ’12, Frederick Kuo ’12, Frank Sweeney ’11, Sarah Feicht ’11, Caitlin Schram ’11, Evan Baugh ’11, Russel Jampol ’11, Dean Clark ’11, and Danica Sheth ’11 received Chemical and Biomolecular Engineering Undergraduate Research Awards. Siah Hong Tan ’11, Ankit Vartak ’11, William Bagdorff ’11, and Sarah Pulicare ’11 received Joseph L. Katz Awards.

Stanley Chung ’11 and David Rezzo ’11 received Loy Wilkinson Awards.

Shu Pan ’13 and Brianna Hafertepe ’12 received Paul A.C. Cook Awards.

Moon Young “Liza” Lee ’12 received the Francis J. Fisher Research Award.

Jessica Miciak ’12 received the Chemical and Biomolecular Engineering Special Service Award.
Undergrad Research: The Chemistry of Aqueous Systems

By Mary Beth Regan

Kelsey R. Dean ’12, a ChemBE major and the daughter of an architect and IBM Corp. software engineer, was pegged as an engineer early. “My family always joked I’d be an engineer,” she says. “When I received a present, I wouldn’t play with the doll. I’d take apart the packaging.”

Still, Dean didn’t think she’d follow her mother into computer programming until she took Assistant Professor Dilip Asthagiri’s Modeling and Statistical Analysis of Data course in the fall of 2009. It was her introduction to data analysis, and she was hooked.

Asthagiri’s lab studies the physical chemistry of aqueous systems using statistical mechanical theory and computer simulations. “We are implementing a new theory to understand ion hydration,” she says. As an undergraduate, Dean is already a co-author on one peer-reviewed article, “Ion-water Clusters, Bulk Media Effects and Ion Hydration,” published in the Journal of Chemical Physics this year (with Asthagiri and graduate students Safir Merchant and Purushottam Dixit). In addition, she worked on research in the summer of 2011 that may result in a second paper with a first-author contribution. In that paper, Dean investigated entropies of hydration to understand the range over which the ion affects liquid water.

Dean has now turned her attention to a third project involving joint research with the lab of Associate Professor Michael Bevan. His team is looking at the properties of γ-crystallin, a protein of the eye lens. Mutant forms of γ-crystallin aggregate and cause cataracts. Dean is trying to understand how the mutation changes the protein-water and protein-protein interactions that lead to protein aggregation and cataract formation.

Dean says being involved in research as an undergraduate has been one of the most rewarding aspects of her years at Hopkins. “It’s been amazing to have been able to take advantage of all these opportunities.”

Graduate Seminar Series Hones Skills

Contributed by Jennifer Tulman and Donny Hanjaya Putra.

For many graduate students, public speaking and presenting their research to an audience can be a daunting task. Yet, a student’s ability to present his or her work at conferences and, eventually, at their thesis defense, is essential to their academic and professional success.

Fortunately, ChemBE’s Graduate Student Liaison Committee (GSLC) provides its members with a way to hone these skills in a constructive and non-intimidating environment. Through its annual summer Seminar Series, the GSLC gives graduate students a chance to present their work before an audience of their peers in a venue that enables feedback and to encourage collaboration.

Last year, the GSLC Sound Bite Seminars required a student from each ChemBE lab to give a 10-minute presentation on the overall themes and techniques they use. The intent is to provide a flavor of the department’s diverse research areas and to foster collaboration between labs.

This year, the Seminar Series reverted to a more traditional format. Senior graduate students (third year and above) presented 25-minute, in-depth overviews of their work, followed by five-minute question and answer sessions. Each week featured two presentations, representing both bio- and nano-technology research. This format allowed the students to practice speaking in front of a friendly audience and receive feedback from classmates from diverse research backgrounds.

Representing nanotechnology, Daniel Beltran of the Bevan lab presented “A Smoluchowski Model of Colloidal Crystallization Dynamics,” and Sumedh Risbud of Drazer’s group gave “Hydrodynamic Interactions at Zero Reynolds Number.” Deniz Baycin (Bettenbaugh), Jennifer Tulman (Ostermeier), and Elad Firnberg (Ostermeier) gave the biotech talks “Impact of Glycosylation and Sialylation on the Neuronal System,” “Directed Evolution of Non-natural Ligand-Activated Enzymes,” and “A One-day, One-tube Method for Creating a Completely Customized 4,000-member Mutagenesis Library.”
Plextronics: Riding the Printed Electronics Wave

By Mary Beth Regan

When WSE leadership was looking for an East Coast addition to the school’s Technology Commercialization Advisory Board (TCAB) this year, members didn’t have to go beyond Pittsburgh for one ChemBE nominee.

Chemical engineering grad James Dietz, ’93 was selected for the TCAB board in part because of his broad experience in the semiconductor and printed electronics fields. John Fini, the Whiting and Krieger schools’ director of intellectual property and technology commercialization, says, “Jim brings a valuable perspective, especially because of his experience with early-stage financing and commercializing university-based technology.”

Dietz, and wife Dina Johnson, BA ’93, Economics, who met at Hopkins, have been on a wild ride since leaving Homewood campus. Dietz spent 15 years in the semiconductor industry before joining Plextronics Inc. in 2007. A Carnegie Mellon spin-off, Plextronics Inc. was founded by another Hopkins alum in 2002, working in large area printing processes using conductive inks, such as those produced by Plextronics.

Analysts have put the market at nearly $300 billion by 2030, with applications including new types of flexible displays, intelligent packaging, intelligent textiles, smart RFID tags (used to set off alarms in clothing stores), and other products.

Industry insiders expect the new technology to usher in an era of “disposable electronics” that allows manufacturers to produce everyday products, such as solar cells, interactive display panels, and bio-sensing bandages, more cheaply. Cell phones, for example, could come with their power sources “printed” right into their plastic coverings.

Plextronics, founded in 2002, is working in three areas: core organic semiconductor materials, printable inks, and device engineering. “We’re right on the cusp of introducing some very innovative products for next generation television applications,” Dietz says.

Dietz, who heads business development, says he is pleased by the company’s recent capital infusion and relationships it has built with stakeholders. In July, the privately held company received an additional $15 million investment from Brussels-based Solvay, its largest minority stakeholder. The company also “inked” a deal with Sanyo Chemical Industries to distribute its Plexcore® inks in the Japanese market.

Dietz visited the Homewood campus and his old stomping grounds in Maryland Hall this fall to meet with professors and colleagues. “I’m excited to reconnect with the engineering school,” says Dietz. “I hope my 20 years of experience can provide additional perspective, especially related to the school’s commitment to entrepreneurship.”

Tom Mansell ’04, MSE ’05, defended his Ph.D. at Cornell in May 2011 and is now a postdoctoral fellow at CU Boulder studying synthetic biology. He married Sarah Goonan, A&S ’04, in May.

Dean Clark ’11 is a systems integration analyst working in the Technology growth platform at Accenture in the Washington, D.C., area.

Stephen Reilly ’10 spent the past year working abroad as a short-term, contracted advanced process control engineer at the Saudi Arabian Fertilizer Company, a Saudi Basic Industries Corporation affiliate, in Jubail, Saudi Arabia, the world’s largest ammonia and urea plant. The experience helped build a solid foundation for all aspects of automation, from multivariable predictive control to PID loop tuning to alarm management and more. Since August he has worked as an associate engineer at ProSys in Baton Rouge, La.

Yagmur Muftouglu ’11 (Yale Pharmacology graduate student), Sarah Schrier ’10 (MIT Bioengineering graduate student), and Rachel Truit ’10 (Penn Bioengineering graduate student) all received National Science Foundation Graduate Research Fellowships.

Mike Keung ’10, MSE ’10, draws from his research experience in the Gracias lab and INBT’s IMEC program as a defect methodology engineer at Samsung Austin Semiconductor. He focuses on defect reduction in a high-volume manufacturing environment that produces large-scale integrated circuits.
Chillin’: A Whale of a Story

By Mary Beth Regan

Now living at Shell Point, a retirement community near Florida’s Sanibel Island, chemical engineer Charles R. Picek fondly remembers his days at Johns Hopkins. These days, in his leisure time, he tinkers with remote-controlled sailboats, operates his 16-foot Hewes Flats boat, fishes, and swaps old engineering stories with friends.

Picek, known as “Charlie” or “Redfish Charlie,” graduated from Johns Hopkins in 1944 with a degree in chemical engineering. During his 50-year career, he specialized in petrochemical, fertilizer, pharmaceutical and environmental process engineering. In addition to pioneering seawater evaporators to make freshwater for ships, Picek (who has sailed many of the Seven Seas in a small sailboat) holds several patents on filters and processes for groundbreaking work in water purification and in situ serum sterilization.

During his career, he was vice president of engineering for Cuno Engineering Co., when it was taken over by AMF, and retired from Pall Corp. in the 1980s. He served as president of the CRP Consulting Group for another decade in Maryland.

Drazer, continued from page 1

“Patients with cancer have a very low concentration of cancer cells circulating in their blood, as few as one in a billion, which makes their isolation very challenging,” Bernate says. “Normal blood cells either don’t express the markers that cancer cells do, or they express them at a much lower level.”

In the lab, Bernate labels cancer cells with particles coated with antibodies specific to these markers. Then, he flows blood samples spiked with the labeled cancer cells through a microfluidic device that has trenches on its bottom surface. These indentations are just a few microns deep, and they are tilted diagonally against the direction of flow.

“If the cells are healthy and none of the protein is present, then none of the particles will stick to them. So the normal blood cells flow easily over the trenches, no problem,” Drazer says. “But the cancer cells, loaded with many particles, are heavier. The trenches act as speed bumps, deflecting the particle-cell complexes laterally.”

In this way, diseased cells can be continuously sorted from healthy ones. If the tagging particles are magnetic, a magnetic field can be used to make the cells “heavier.” This allows for faster flow and makes it possible to process a sample of blood more quickly. Using a fluorescent tag, the researchers can monitor this separation process visually under a microscope.

Drazer works with Department Chair and ChemBE Professor Konstantinos Konstantopoulos on this research. “What drives me is investigating these interesting problems of basic science,” Drazer says.

In his doctoral dissertation, and his related papers describing complex transport through porous media, such problem defining and solving have been the essence of Drazer’s work. Drazer’s mathematical penchant most likely stems from his training, not as a chemical or biomolecular engineer but as a physicist at the competitive Instituto Balseiro (IB) in Bariloche, Argentina. Drazer earned both a master’s and a doctorate at IB and then completed postdoctoral work at the Benjamin Levich Institute for Physico-Chemical Hydrodynamics at the City College of New York. He joined the Johns Hopkins faculty in 2005 and was awarded the prestigious National Science Foundation CAREER Award in 2010. Today, his work is also funded through NCI Johns Hopkins Physical Sciences in Oncology Center.

Drazer hopes his background and training bring some simplicity and order to the complex world of separation sciences. “Often in the separation systems, there are many variables and processes are usually very complicated. I like reducing problems to a minimum number of variables,” he says.

Konstantopoulos describes Drazer’s work as “archival,” or relevant to many disciplines. “German focuses on discovering and describing the basic truths about questions relating to separation science and then elucidating these facts in the form of equations that will remain valid in every circumstance. Others work by trial and error,” Konstantopoulos says. “German works with numbers, which are absolute. This is one of the many strengths I think he brings to the table.”
Extracting Algae’s Promise

Algae have the potential to be a mainstay of sustainable bioprocessing as a versatile photosynthetic production platform for pharmaceuticals, nutritional commodities, and biofuels. But if this potential is to be realized, significant technological hurdles in the oil extraction and separation process—ones that eliminate the need for hazardous solvents and reduce costs—must first be addressed.

A group of JHU researchers, including ChemBE professors Marc Donohue and Michael Betenbaugh and PhD student Julian Rosenberg, are working with George Oyler of Synaptic Research and Clean Green Chesapeake to develop a new CO$_2$-solute extraction method that enhances the extraction efficiency of oil from wet algal biomass in a pressurized system.

Researchers determine the optimal conditions for extracting oil from algae using CO$_2$. This research has the potential to be profound because of the positive environmental effects and because algae is a largely untapped source of alternative energy. Cultivating algae could help reduce pollutants in the Chesapeake while providing alternatives to traditional fuels.

The competition in this field is fierce because of the potential profit from successfully utilizing biofuels. The Betenbaugh-Donohue groups face challenges, but their collaboration with top researchers in algal studies gives them a competitive edge.

George Oyler, MD, PhD, president and founder of Clean Green Chesapeake, says, “Algae has enormous promise for environmental enhancement, improvement of agriculture and aquaculture productivity, and to sustainably support our energy needs, particularly for liquid transportation fuel.”