Parkside JOURNAL OF SCIENCE

VOLUME II ISSUE II

IN THIS ISSUE:

UNIVERSITY OF WISCONSIN PARKSIDE

EDITOR'S NOTE

THOMAS STIRRAT
Editor In Chief

KATIE ANDRESEN
Executive Editor

Dear Reader,
We are excited to bring you this latest edition of Parkside Journal of Science. Our semesterly publications feature a collection of both articles that spotlight relevant scientific research and interviews with students and faculty in the College of Natural and Health Sciences. It is our goal to bring more awareness to the research being done here at UW-Parkside and around the world.

As we continue to navigate through the COVID-19 pandemic and adjust to the continuous changes in our world, it is imperative to highlight advancements in all fields of science. It is our hope that the Parkside Journal of Science has and will continue to accomplish this goal of emphasizing some of the latest research in areas that are directly impacting our lives. In this issue, we bring together an array of articles and interviews highlighting research in the fields of biology, chemistry, and physics, with a variety of disciplines represented in each.

We feature articles that discuss ongoing issues amidst the pandemic, changes to the natural world around us, advancements in medical research, and much more. This issue additionally calls attention to some of the research being conducted by students and faculty in the chemistry, physics, and biology departments here at UW-Parkside in hopes of bringing to light the many opportunities our school has to offer for students.

We thank you for taking the time to read this edition of PJS, and look forward to continuing this work in the volumes to come.

Sincerely,

Thomas Stirrat, Editor in Chief and Katie Andresen, Executive Editor

FACULTY ADVISOR'S NOTE

HOM KANDEL, PHD

It is a great pleasure to present the new issue of the Parkside Journal of Science to our readers.

I want to take this opportunity to extend my warmest thanks to all the editorial board members and student writers and the Marketing and Design team, Faculties, and students in the College of Natural Health and Sciences for their outstanding support towards this journal. I am so happy with the contribution they have made through their creative works to publish this issue.

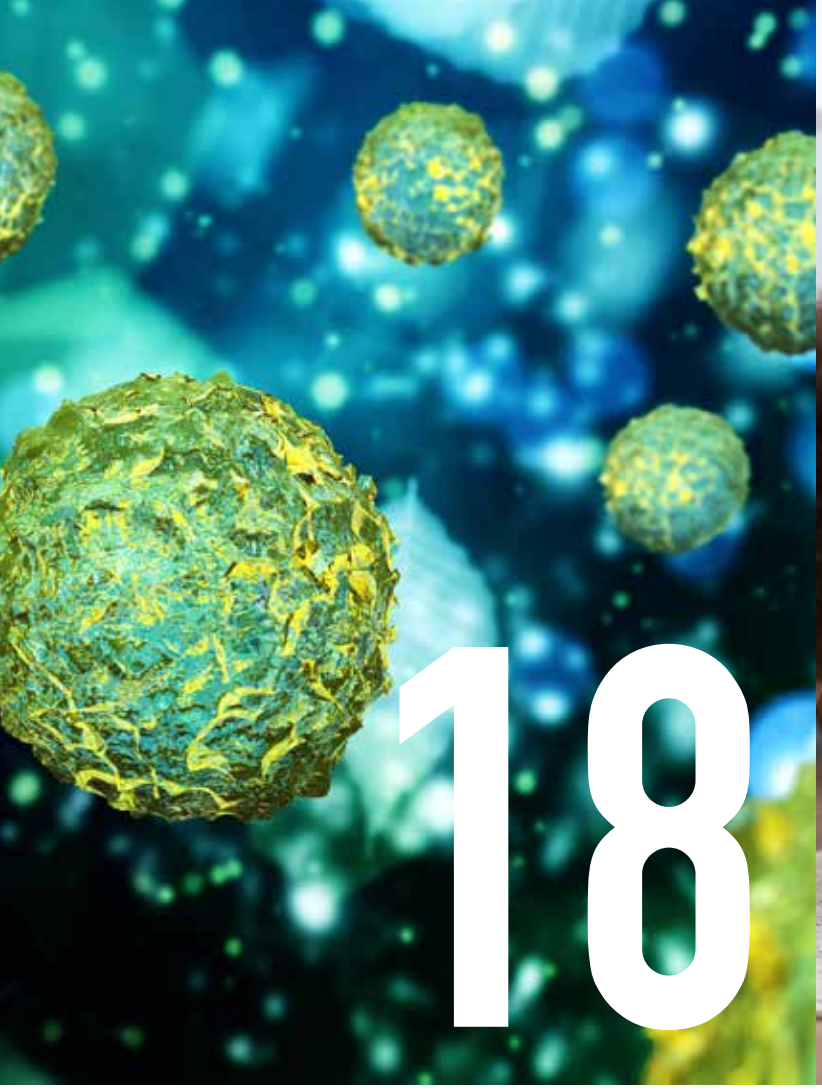
This issue contains the motivational interview of Physics Professor Paul Mohazzabbi and an interesting physics article on superconductivity. Other exciting articles include "asymptomatic but still positive," cancer biology, artificial light, protein folding, climate change, etc. We promise faculty and students at the CNHS to provide them a great platform to disseminate their research in our journal.

Thanks again for taking the time to read the new issue of the Parkside Journal of Science. I hope you will find the articles and the interviews fascinating and informative.

Sincerely,

Hom Kandel, PhD

Advisor, Parkside Journal of Science



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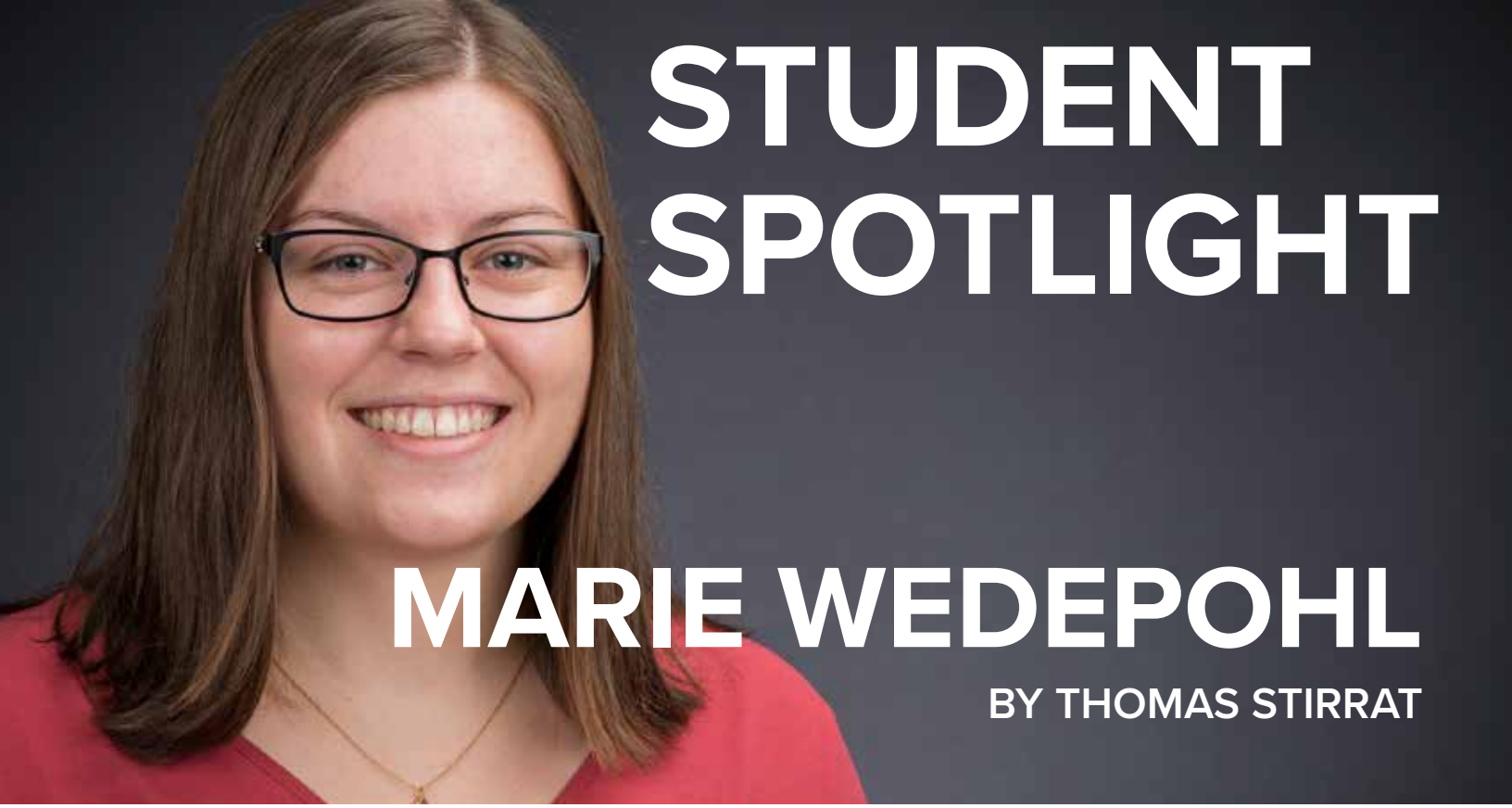


STUDENT SPOTLIGHT

MARIE WEDEPOHL

BY THOMAS STIRRAT

Tell me about yourself
I grew up on a hobby farm (meaning all the farmland but no animals) in Reedsville, WI about 40 minutes south of Green Bay. Because of this, my hobbies pretty much include doing anything outdoors, especially hunting, hiking, swimming, and running. I love my two dogs (Weimaraners), Hanna and Blu, so anything that I do that they can join me, I will always bring them with me. I also love wrestling and traveling. I wrestled my whole life and on the boy's varsity team throughout high school so I really enjoy watching the sport and whatnot. I have traveled a lot of places but my favorites have been: Thailand, to visit a foreign exchange student who lived with us in the US; Australia, for that same reason; Roatan, Honduras for a medical mission trip; and Arizona.

What made you come to Parkside?
I came to Parkside for a lot of reasons including the price, being relatively close to my home and family, and the small size. Parkside is one of the most affordable colleges in Wisconsin and because of its small size, I felt like I could be supported there. I am not one that really loves big cities, so the location was super appealing to me being next to Petrifying Springs. I also met with Dr. Lewis and Mary to talk about the pre-med program since that's what I knew I wanted to do, and they made me feel like Parkside would give me the education, experiences, and support that I needed to achieve my goals— which they were right about.

What were your favorite parts of Parkside?
Honestly, the people. Everyone at Parkside, whether it's the students or faculty, are all so kind, supportive, and very down-to-earth. I made so many friends and whenever I was struggling with a class or personal issue, I always had someone I could go to. Everyone there wanted to learn, and the professors were so dedicated to helping students succeed, that I enjoyed my learning experience so much more because of all the people and their mindset.

Were you involved in any clubs at Parkside, if so which and to what degree?
I was very involved in a couple of clubs. I was most involved with the pre-health club. I was a member for my entire time at Parkside and I served as the vice president my sophomore year. As vice president, I helped coordinate all of the volunteer activities and some of the speakers that came in. Every year, I participated

in a lot of their volunteer events and attended most meetings. I was also involved in Habitat for Humanity where I volunteered with them and Cru, a Christian organization where I took part in Bible studies.

Why did you decide to major in Biological Sciences and what are your career aspirations?
I decided on a biology major because I knew I loved science, and the courses also aligned with what I would need for medical school. I liked the overarching theme of biology where I was able to study all forms of life and how living things function. I also loved chemistry because of the complexity and details it made me think about, so I also decided to get a chemistry minor. I want to be a physician and practice rural medicine, but I'm still unsure about what specialty.

Why did you decide to go into medicine?
There was never a singular moment that I decided I wanted to pursue medicine, but a lot of little moments that led up to me deciding I wanted to become a physician. I have always been a curious person and love learning, especially about science. When I realized that medicine meant combining science with helping people, I became interested in medicine. Then, over several years, I saw the positive impact that physicians and other medical professionals made with helping people I love to recover from several health issues. This made me want to combine my curiosity with my love for science and learning to become a physician.

Where do you see yourself in 10 years?
In ten years, I hope to be a practicing physician in a rural area.

Can you think of a specific role model who encouraged you down this path?
In a way, yes and no. I don't have any physicians in my family or family friends, so trying to become a physician was something I decided to do on my own and I never had a role model in that aspect. However, I would say that my parents are my role models in another aspect since I look up to them in many ways. Their support has allowed me to pursue whatever I set my mind to without putting any barriers on what I could and couldn't do. Having them by my side with everything I do allows me to believe in myself to accomplish all of my goals.

What kind of research are you involved in?
I do fish morphology research with Dr. Taft. Our goal is to compare the bone density of different hemitrichia (one part of a fin ray) between different species of fish. This is to determine the differences between intertidal and subtidal fish bone ossification due to the conditions they live in and the methods they use for locomotion.

As a part of Dr. Taft's lab, what projects are you a part of?
I have been involved with one project over the last three years as I mentioned above. I have been involved in each step of the process to analyze the CT scans we have of the different species of fish. This has involved many steps from finding the correct fin rays to analyze on the CT scans, to obtaining measurements, to cropping the 3D images in the right spot, and then using another program in order to obtain the correct measurements and calculations of different hemitrichia of the fish to be used for comparison.

Tell us about your favorite part of your lab work.
All of the lab work I do is actually on the computer since I am analyzing digital CT scans of the fish. My favorite part is learning how to use different programs to obtain the necessary measurements. I have been able to use my curiosity to learn the ins and outs of the programs (Horos and ImageJ) in order to develop the best and most efficient methods to obtain the measurements we need for the fish.

What do you enjoy most about doing research?
I love the fact that I can do my research from anywhere because then I can work on it at any time (even now that I am graduated). I also like that I was able to use my sense of curiosity to go through all the functions of ImageJ to help develop a method for obtaining the bone density of each hemitrichia.

What have you been doing since graduating from Parkside?
I am living at home and working as a CNA at a local nursing home (and got vaccinated—yay!!). I was able to go on a pheasant hunting

trip with my parents and our two dogs in Iowa, where my brother lives. I also was able to go help out two high school girls with wrestling practice and watch them compete at girls' state wrestling. I am also currently working to finish up my research project with Dr. Taft and trying to plan for my move to Madison in the summer! In general, I am just trying to enjoy my free time and safely spend quality time with my family, friends, and dogs.

Do you think there need to be more females in STEM? How could we attract additional students to become interested in this field?
I absolutely think there need to be more females in STEM. I think encouraging and supporting every female who is already in STEM to continue is the first step. By keeping females in STEM, provides role models for younger females. I really think seeing someone like you in a STEM role gives young women the ability to see themselves in that sort of position and make that a goal of theirs. This, along with encouraging women from a young age to pursue whatever interests them (without imposing any barriers to what they can and cannot do) and providing them with information about STEM careers can help.

What were you most stressed about during undergrad?
I would say maintaining a perfect GPA was what stressed me out the most. Anytime I messed up an exam or my grade was on the edge, I got extremely stressed out. Looking back, I know I could have given myself a break more often and let go once in a while because perfect grades do not make a perfect applicant for professional programs. I see now that programs are looking for well-rounded applicants who embody many characteristics, not just perfect grades and I wish I would have given myself a break more often.

What challenges did you overcome in your education at Parkside?
I was very fortunate to not have any significant challenges to overcome while at Parkside. In general, the thing I struggled with the most was balancing everything that was going on in my life from classes, to work, to volunteering, to my personal life. There were many times where I felt overwhelmed and wasn't sure that I could handle it all so I reached out to close friends and mentors who helped me find balance through it all.

How do you think you benefited from a Parkside education?
I think the biggest way I benefitted was from the small community at Parkside which allowed me to form relationships with other students and staff here. Having small classes allowed me to know each of my professors and get their help with anything that I was struggling with in class. Knowing so many people also opened so many opportunities for me around campus such as volunteering and getting a job at the Parkside Academic Resource Center as a Supplemental Instruction leader and tutor. Knowing my professors directly also helped me get letters of recommendation for my internship and for medical school. Knowing that the faculty at Parkside was always there to support me definitely helped me keep motivated and work hard to obtain my goals.

What healthcare experiences were you involved with prior to applying to medical school?
I obtained my CNA license my senior year of high school and started working as one after graduation. I worked almost every summer and winter break until I graduated. During my freshman year winter break I also traveled to Roátan, Honduras to volunteer at Clinica Esperanza for a medical mission trip. While there, I triaged patients and took their vitals before they saw the doctor. I was also able to shadow medical professionals there and perform health screenings on children in a local community that was about to start school. I also was able to do some shadowing with physicians, physician assistants, and other medical professionals throughout undergrad.

What volunteering were you a part of during undergrad?
I did a lot of volunteering through the pre-health club which included events like Earth Day and Make a Difference Day cleanups as well as packaging food at Feed My Starving Children. I also did some volunteering through Habitat for Humanity and other random events that Parkside needed help with. My trip to Roátan, Honduras at Clinica Esperanza was all volunteer work so that was a huge part of my volunteer activities for me. I also volunteer through a nonprofit organization

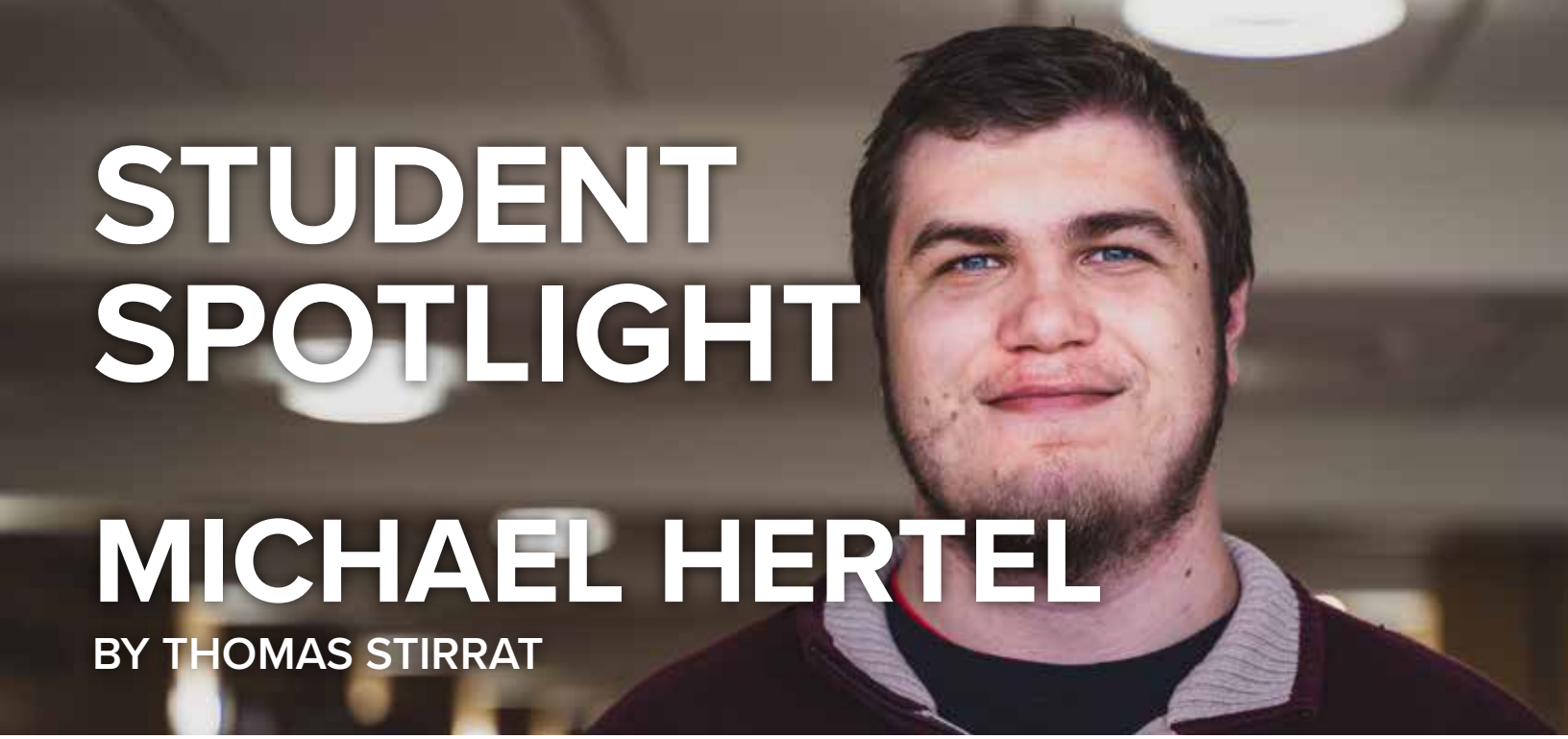
back in my hometown called Shoot for Coop which is in honor of our neighbors' son Cooper who passed away in a tragic accident. Each year, we host an event with trap and archery shooting, food, raffles, and a silent and verbal auction to raise money for the Children's Hospital of Wisconsin and other local charities. I help each year mostly with running the event the day of and also with cleanup and setup.

What are you most excited about for medical school?

I am excited to have my education be exclusively focused on the human body and all of its functions and the treatments for different medical conditions. I am also excited to take that knowledge and apply it to clinical practice in order to help patients heal from their medical conditions. Along with this, I look forward to doing different rotations in order to find out what field of medicine I want to pursue for my residency.

Who is someone from Parkside that you look up to?

I honestly look up to so many people at Parkside so I cannot choose just one person. I really look up to Dr. Lewis because of his ability to mentor, motivate, and encourage students from all different walks of life with a wide variety of goals. His ability to relate to students and understand exactly what they are going through or may need in order to help them through whatever they are dealing with is amazing, and I hope one day to be able to impact my patients that much. I also look up to Dr. Taft for her authenticity. She has the ability to teach her students while being genuine with them about life. She has shown me that you can take on multiple roles in life such as being a woman in academia while also being present with her family and involved in the community. I look up to Dr. Taft and Kim White (my boss at the Parkside Academic Resource Center) since they have taught me so much about being a more open-minded and accepting individual and just a better human being in general.



STUDENT SPOTLIGHT

MICHAEL HERTEL

BY THOMAS STIRRAT

Tell me about yourself
My name is Michael Hertel and I just graduated this past fall with a degree in molecular biology and bioinformatics. One of my favorite things to do is play video games with friends. I also enjoy watching the Blackhawks, Cubs, and Steelers. I am interested in pursuing a Ph.D. in molecular biology.

What made you come to Parkside?
I wanted to prepare myself for graduate school and I wanted to stay close to home for my undergraduate degree. Also, Parkside's MBB degree gave me an opportunity to be able to perform research and prepare myself for graduate programs.

What were your favorite parts of Parkside?
I enjoyed the smaller class sizes and interactions with professors. Being able to talk with the professors when I needed and forming connections, I felt allowed for me to better be able to learn from them.

Were you involved in any clubs at Parkside, if so which and to what degree?
I wasn't involved with any clubs until my last few semesters, and not being involved in clubs earlier is something I regret. The last 3 semesters I was a part of the Parkside Journal of Science, and I was able to co-author an article on a Dr. Higgs interview.

Why did you decide to major in Molecular Biology and Bioinformatics and what are your career aspirations?
My career goal is to obtain a Ph.D. in molecular biology, and Ph.D. programs require research experience. The MBB program requires 2 semesters of research experience, so this major would allow me to get the experience needed for grad school.

Where do you see yourself in 10 years?
I hope to be a professor where I have my own lab and am also able to teach classes. As a professor, having my own lab would allow me to conduct research on the topic I wish, and being a professor also means teaching. I would like to be able to teach classes where I will be helping students on their journey through college.

Can you think of a specific role model who encouraged you down this path?
My father had inspired me to follow my passion. Nobody really inspired me to become a scientific researcher, but my dad has been my role model. He encouraged me to try different things and keep looking through my interests to find something that I want to do. Once I found research, I knew what I wanted to go to college for, and I have him to thank for pushing and encouraging me to find out what I want to do.

What kind of research are you involved in?
I was working on identifying if there was a mutation and characterizing the mutation if there was one in Chlamydomonas reinhardtii. In this type of research, I was working with an organism that was suspected of being a mutant, and with the unknown presence, I had to develop various scenarios for testing. I also had to test the mutant under various stresses to try and elicit a phenotype. These mutants are from the Chlamydomonas Library institute (CLiP) and are generated by adding a cassette of DNA into a section of the genome. The cassette includes an antibiotic resistance gene, predetermined primer location sites, and an internal sequence to identify each cassette. Even though there is supposed to be a mutation, there are instances where the mutation is not there or is in a different location than expected.

As a part of Dr. Higgs' lab, what projects are you a part of? What did you learn about?
I worked with the 13-1 strain and had to use a variety of lab techniques throughout the process of characterizing it to discover if there was a mutation. After DNA isolation, I was able to use multiple rounds of PCR testing in order to determine that there was a mutant. I learned how a technique like PCR can be used in conjunction with DNA sequencing in order to find both a possible mutation and the sequence of the region to discover the change. By using primers in PCR, a specific band of DNA will have approximately a billion copies generated in the course of 3 hours. This band can be placed into an agarose gel, and through the process of electrophoresis migrate through the gel where the band can have its length approximated. If the band is extracted and cleaned from the gel, it can be sent for sequencing with the primers used. To sequence the DNA, I had to prepare a set amount in nanograms with one primer used in the PCR and the remaining volume with sterile H2O. Each band needed to be processed with both primers separately since sequencing only is performed in one direction. Once the mutation was confirmed, growth curves were performed to see if a different phenotype would occur. I learned that various methods used to stress Chlamydomonas were growing it in 10% available nitrogen (N10) and without acetate (Min). Something I learned about Chlamydomonas is that it can take up acetate from its environment to use as its carbon source or photosynthesize, and in Min media, we are forcing it to photosynthesize to see if there is a mutation relating to the chloroplast.

Tell us about your favorite part of your lab work.
My favorite part of lab work is testing the unknown. I did this when using PCR to generate bands that could be sequenced in order to confirm the presence of the CLiP insert. Conducting growth curves was also testing an unknown because the confirmation of a mutation doesn't guarantee a different phenotype will be observed. Lastly, the insertion of the CLiP cassette was not clean resulting in a truncation, which was later found to be a section of chromosome 10, but the chromosome the insertion was in was chromosome 4.

What do you enjoy most about doing research?
I really enjoyed the aspect of not knowing the answer to a problem and having to work through that problem methodically in order to have a solution that is correct. For example, the mutant had a truncated mutation and the 3' end of the insert couldn't be identified, so a PCR that targeted the 3' end was designed in order to solve that unknown.

What have you been doing since graduating from Parkside?
I have applied to two different graduate programs, the Cellular and Molecular Biology Ph.D. program at UW-Madison and the master's program at UW La Crosse in biology. I was not accepted into UW Madison, but I was accepted into the master's program at La Crosse.

Do you think there needs to be more researchers in STEM? How could we attract additional students to become interested in this area?
I do think there needs to be more researchers in STEM, and I think COVID highlighted the impact of researchers. STEM researchers impact people's lives in a variety of ways, and I feel they are often taken for granted. I think that if STEM is connected to daily life earlier in

schooling, then children may take more of an interest in a STEM field and find a passion in it. To do this I believe there needs to be more funding into the school systems throughout the levels of schooling in order to give STEM fields more exposure.

What were you most stressed about during undergrad?
My goal was to complete my undergrad in order to continue my education, so I think the biggest stress was for me to make sure I was as qualified as I could be for grad school.

What challenges did you overcome in your education at Parkside?
When I first started at Parkside I was doing really well, but as my classes became more difficult, I started to do worse, so my biggest challenge was probably changing the ways I learned and studied to better suit me rather than use the ones that got me through high school. Some of the things I changed was I would write notes in advance if I could and in-class add to them, then after class, I would rewrite my notes. I also changed how I took notes, before I would write everything down, but I changed it so that I was only writing down new information or information that connected topics together. This way I was writing less which saved me time in order to be able to rewrite my notes.

How do you think you benefited from a Parkside education?
I felt like I was able to learn more efficiently in smaller class size. I was also able to participate in undergraduate research at Parkside, and I believe this made me stand out as an applicant because it wasn't just a summer, but I ended up doing research for 3 semesters.

What are you most excited about for graduate school?
I am looking toward the new experiences that I will have being in a different lab and meeting new people.

Who is someone from Parkside that you look up to?
The person I look up to most at Parkside would have to be Dr. Higgs. I was able to be in his genetics lab, molecular biology class, and in his lab for 3 semesters. He made sure that everyone understood the material and would always take time for his students. When I was in his lab, he was always encouraging but never demanding, and it made me feel more comfortable and confident. When he teaches you can always see the passion he has for the material in his lectures. I have a tremendous amount of respect for him, and if I become a professor, then I want to be a professor to students like Dr. Higgs was to those at Parkside.

PATENT PROFESSOR AND PROLIFIC INNOVATOR DR. MANN

BY LEAH POULOS

When did you first become interested in being a scientist?
This may be a nerdy answer, but my parents were really into science fiction and I remember when Jurassic Park came out I thought that being a scientist looked really cool.

How did you decide to be a biochemist?
In high school they had us take career aptitude tests and mine suggested biochemistry or biochemical engineering. I knew I didn't want to do pharmacy or medicine, so I figured I could get a degree in biochemistry and then teach high school, but I never thought I would get a Ph.D. Towards the end of my undergraduate studies, I realized that I could make just as much money going to graduate school to get a Ph.D. as I could teaching high school, so I decided to apply, hoping that someone would let me run my own lab someday.

How did you get started doing research?
I knew that I wanted to do undergraduate research, so when I was applying to colleges, I looked for places that had good programs and ended up choosing Nebraska. At school, I started talking to biochemistry professors and one guy, Han Asard, had an opening in his lab studying antioxidants in plants. I worked in his lab for a year and a half until he left the university and then began in another lab where I really gained my independence.

What made you choose this field (Microbial Natural Products)?
During my undergrad, I worked in a biochemistry lab that focused on plants and then got a fellowship in another plant lab for graduate school. As I was working in this lab, my PI started a project with Mycobacterium tuberculosis and said that someone had to

work on it, so I volunteered and split my time to work equally on my original project. I knew after graduating that I wanted to work in an undergraduate and master's level research setting with people who need more experience, so microbes were a better choice and I ended up shifting to microbial natural products. Additionally, my PI allowed me to take all my research from my graduate studies and start my own lab with it, which is practically unheard of.

How would you describe your research to someone lacking a background in science?
My lab is interested in determining how microorganisms can improve the function of human medicine and industry. We use microbes to make compounds more bioavailable, increase their bioactivity or make new natural products.

What projects are you working on now?
I have four different projects currently. The first, which is funded by the 2020-2021 WiSys Ignite Grant, is assessing novel methods for the production of carotenoids for aquaculture feeds. My lab and Dr. Taft's lab are looking at bacterial and fungal sources of carotenoids to support the Wisconsin fisheries that require pigmentation (e.g. trout and salmon). The second, for which I received the 2021-2022 UW System Regent Scholar Award, is a branch of my Mycobacterium tuberculosis project that is focused on determining how a novel, natural product produced by one bacteria is appearing to kill another bacteria. The third is studying kombucha, which acts as a hypoglycemic agent and has been shown to have antilipidemic activities in animal models. My lab has previously demonstrated that these effects are due to microbial fermentation of the compounds in tea and now we are trying to characterize these compounds. The last project is the only one that doesn't have students involved currently; in previous semesters, my students worked to extract anthocyanins from cranberry waste using mixed bacterial fermentation. Right now I'm in the process of negotiating licensing of the patent that I submitted from this project and this is the first time I'm going through the industrial licensing process.

What do your day-to-day activities in the lab look like?
While my activities vary between the school year and summer, on any given day I may be coordinating one to three experiments with different groups of students. My role in the lab is often as a teacher and mentor, rather than doing benchtop work. My goal with new students is to show them how to do an experiment or technique once, be there when they do it the second time, and then after, work with students who need help directly and be around to answer questions that more independent students might have.

As a follow-up to that, do you miss doing benchtop work?
Opportunities are always there for me, especially during breaks, but it's hard to do while also working with students. Typically when I start a new project, I'll do a few experiments before handing it over to my students, who are actively involved in developing the research plan, performing experiments, interpreting the data, and presenting the outcomes. I would say this happens 2-3 times per school year and 2-3 times per summer.

What is the most difficult aspect of your research?
Replicability is probably the hardest thing. In other fields of chemistry, such as organic synthesis or analytical, this isn't as much of a problem, but as a biochemist, there're so many variables that are much harder to control because you're working with living systems.

What is the most rewarding aspect of your research?
Honestly, patents, papers, and grants are all fun but the most rewarding moments are when my students go "aha" and understand new things or their experiment works. I love being able to work with them and watch them become independent scientists.

Who is a mentor that you look up to and why?
There are two people who immediately come to mind. The first is a man who was doing post-doctoral research in my undergraduate lab in Nebraska and noticed that I wasn't getting much help from my PI. I was following laboratory protocols but wasn't getting results

and he told me that I could change anything in my experiments until I found something that worked as long as I kept track of what my changes were. That piece of advice changed my perspective of what science was and how I went forward with my research. The second is Jennifer Doudna, one of the two Nobel Prize in Chemistry recipients for her work on CRISPR/Cas9. I read a biography on her recently where she talked about how she was looking for a new challenge so she went to work for a biotechnology company, quit within two months, and went back to academic research. From this experience, she realized that she had been playing it safe and learned she could try new things without extremely bad consequences, which is something that I really appreciated reading.

What is your approach for attracting bright minds to research?
I like to recruit younger students who have only gotten basic skills from their introductory courses and labs and provide them the research experience they need to gain skills that will make them successful in their future.

How many patents do you have?
I have five patents. The first one was filed in May 2010 during graduate school after we discovered the Isotuberculosinol Pathway in Mycobacterium tuberculosis. The most recent one was filed in March of 2020, with one of my students listed as the co-inventor, after we discovered a novel, isoprenoid from Mycobacterium tuberculosis with potential bactericidal activity.

What accomplishment are you most proud of?
I'm proud of every accomplishment. I didn't ever expect to get my Ph.D. and when I start new experiments, I'm never confident that they are going to work out, but they have. The most important thing that I've learned is that even if I don't know how to do something, I need to show up and try it out because if I don't try then I'll never know.

THE IMPACT OF ARTIFICIAL LIGHT AT NIGHT ON EVOLUTION

BY KAITLYN ANDRESEN

With the rise in urban development, the amount of artificial light at night has been steadily increasing. ALAN for short, this change has had a number of impacts on populations of animals living in urban areas. The effects brought on by ALAN have been studied and characterized in a number of animal populations, and have been shown to have strong impacts in animals with a phototactic response, causing changes in reproductive biology and behavior that may in turn lead to evolutionary development.

Phototaxis is defined as an organism moving closer to or further from light, and it is no surprise that ALAN plays a large role in phototactic response and related behaviors. Animals with a negative phototactic response (a tendency to move away from light) may leave a location that has been illuminated by ALAN. Conversely, animals with a positive phototactic response may find themselves drawn to such a location. In addition to the immigration and emigration of animals due to this response, it has been suggested that predators may target organisms displaying a positive phototactic response. The presence of ALAN, therefore, has a number of implications on animal populations due to natural selection based on phototactic response, with animals displaying positive phototaxis being selected against (Hopkins et al.).

ALAN has additionally been found to lead to differences in reproduction among animal populations. One study showed that birds living in an urban area experienced a longer breeding season and earlier development of reproductive organs. These were advanced by a number of weeks in one observed species of blackbirds. However, as the breeding seasons are changed due to ALAN, what about those species with a lower presence of artificial light? Breeding behaviors have no need to change in such populations, and this difference may therefore lead to temporal reproductive isolation between urban and rural populations of animals (Dominoni et al.).

In addition to differences in reproductive behaviors, animals have also been found to exhibit changes in their everyday routines. One notable change is the time at which animals eat. Studies have shown that animals subjected to

ALAN eat more at night than their counterparts. This time change leads to disruption of an animal's metabolism, which has been linked to weight gain (Fonken et al.). Another observed difference was in the time of molting. One study reported that birds living in a city began molting an average of 13 days before those living in a forest (Dominoni et al.). While ALAN may increase or advance behaviors in some animals, it may decrease them in others. For example, there has been an observed drop in communication in frogs, which may lead to changes in levels of reproduction (Russart and Nelson). Overall, these behavioral differences may in time lead to major changes in population size and may offset predator-prey interactions to a great degree.

The changes associated with ALAN may in turn lead to genetic drift. Populations experiencing ALAN may see a drop in immigration as those individuals that are drawn to the light may be selected against. The individuals that do survive in a brighter location will by way of natural selection differ from their counterparts in the low-light locations. The changes in behavior that are associated with ALAN will additionally divide species, as new feeding and reproductive times arise. All of these changes may lead to reproductive isolation (Hopkins et al.). As urban development continues to spread, the effects of ALAN will become more readily apparent, and as species diverge and change we may begin to see even greater alterations to the world around us.

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CANCER RESEARCH 2020

BY GABBIE JENSEN

COVID-19 took center stage in the health field during 2020. Consequently, much of the research and work done in other medical fields have been overlooked by the public. It is therefore necessary to highlight the critical works of researchers in such fields— notably, cancer research. Despite decades of intensive work, cancer, in all its forms, is still one of the most persistent and potent issues in health today. However, each year, new breakthroughs are discovered as we inch closer and closer to curing this deadly group of diseases. One recent breakthrough is the use of highly-regenerative mesenchymal stem cells.

Stem cells are unspecialized cells that can grow into any of the body's over 200 different cell types, including skin cells, liver cells, and muscle cells (William C. Shiel Jr., 2017). These cells are arguably the most important cells in our bodies because, unlike most differentiated (specialized) cells, they continue to divide and propagate throughout our lifetime. The ability to accomplish this comes from telomerase, an enzyme that slows cell aging. Although telomerase's function is beneficial in the case of stem cells, it is also what causes cancer to proliferate (Johnson, 2009). Stem cells then grow into whichever type of cell needs to be replaced.

The importance of stem cells is due to the fact that our specialized cells are constantly dying. Most individual specialized cells do not live for a long period of time, especially the cells that are most commonly exposed to the outside environment, such as skin cells. If a skin cell dies, a stem cell can specialize and become a new skin cell to replace the old one. This is how and why our tissues are dynamic; we do not have the same cells our whole lives, they continually go through the cycle of dying and being replaced. Not all types of cells are able to go through this process, however. These include most brain cells (neurons), eye cells (rods and cones), the specific cells in our ears that aid in hearing, beta cells in the pancreas (death of these is associated with Type 1

diabetes), and some cardiac cells. We are born with a finite number of these cells, and they are generally not replenished (Ferens, 2018).

All higher animals, including humans, have three main tissue layers when first developing, and are therefore called triploblasts. These layers include: the ectoderm (the outer layer), the mesoderm (the middle layer), and the endoderm (the inner layer). Although these tissues are very basic at first, they each develop to form critical parts of the body. The mesoderm specifically goes on to form the skeletal system, the muscular system, the excretory system, the circulatory system, the lymphatic system, connective tissue, and the reproductive system (Editors, 2017).

Mesenchymal stem cells (MSCs) were first discovered in the 1990s in bone marrow tissue. They have been found to have a high differentiation potential, meaning that they are efficient at specialization. They also have self-renewal properties, indicating that they can effectively propagate. MSCs can give rise to multiple types of cells, including osteoblasts (bone forming cells), chondroblasts (cartilage forming cells), myocytes (muscle cells), and adipocytes (fat cells) (Timaner, Tsai, & Shaked, 2020). MSCs exist at extremely low frequencies in the body, found mostly in the bone marrow where they originate. However, they do occupy other organs, such as the peripheral blood (the flowing, circulating blood of the body), the placenta, the umbilical cord, lungs, and muscle (Manal, 2019). In such organs, they perform important anti-inflammatory and structural functions. Additionally, due to their differentiation and self-renewal abilities, they function strongly in wound healing- that is, the regeneration of cells. When something such as a wound disrupts the body's equilibrium, the chemical types and quantities flowing through the endocrine system are altered. These chemical signals from regions of the body are recognized by MSCs and direct them to the specific wound site, where they can then perform their regenerative function.

Unfortunately, because they are quick to react, MSCs can also be used against the body's functioning. It has been found that these cells are used by cancerous tumors to promote their uncontrollable growth and metastasis (spread) because tumors are recognized by the body as chronic, non-healing wounds (Timaner, Tsai, & Shaked, 2020). The MSCs attempt to heal the "wound", as this is what they are programmed to do, but wound healing usually entails replacing dead or damaged cells with new ones. Due to the fact that tumors are an uncontrollably-growing mass of cells, the MSCs' attempt to "heal" the body actually helps the tumor by creating more malignant cells. MSCs are therefore considered to have both pro- and anti-tumorigenic properties. These cells also contribute to tumor resistance to drugs and treatments such as chemotherapy (Timaner, Tsai, & Shaked, 2020). Despite having fallbacks in cancer prevention, MSCs' unique properties make them good targets for pioneering cancer treatments.

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THE NEW AGE OF SCIENCE

BY CHANDU GOLI

Computers were invented with the goal of automatic computation, a task that mimics the complex automatic processes of the brain. At first, its main uses were for simple mathematical computations, however with the advent of machine learning and artificial intelligence, the trajectory for technological advancements has been exponentiated. The field of molecular biochemistry has greatly benefited from computational artificial intelligence. A long-standing quandary in this community has been the "Protein Folding Problem." It is essentially a riddle that aims to understand how exactly a sequence of amino acids enables the production of a three-dimensional structure of a protein. This is the key to making our very own biological machines, understanding proteins, diseases, drug-development, and much more.

CASP, or Critical Assessment of Structure Prediction, is a computer-based protein structure prediction competition started by John Moult in 1994. Contestants are given amino acid sequences of proteins that have already been experimentally structured but withheld from the public, and are tasked to accurately predict the correct three-dimensional shape. Competing teams try different state-of-the-art techniques to implement in their various programs to predict the correct folding patterns of the given sequences. 2020 brought about the 14th iteration of CASP with major leaps. One contestant this year, AlphaFold, dominated the competition, achieving consistent predictions of over 90% accuracy for more difficult proteins compared to an average of around 75% accuracy by other contestants on the same proteins.

As best explained by Elon Musk, an avid investor of the company, "Deepmind is a semi-independent subsidiary of Google; focused upon creating digital super intelligence; an AI that is vastly smarter than any human on earth and then all humans on earth combined". Deep learning started to be incorporated into techniques used by CASP participants in 2012. Its full potential wasn't observed or realized until 2018, with Deepmind's initial entry of AlphaFold into CASP13. In its first version, Deepmind implemented a convolutional neural network to analyze a given sequence of amino acids and predict the pairwise distances and torsional angles that would occur between residues to ultimately generate a three-dimensional structure of the protein. This was the model that was first used during CASP13 in 2018, in which AlphaFold1 was able to predict a protein structure with an accuracy score of 68 Global Distance Test (GDT) compared to the runner-up's score of 48 GDT. GDT is the unit used to measure the accuracy of a predicted protein structure compared to the correct known protein structure, and is the degree to which the amino acids are positioned correctly. AlphaFold2 improved on its findings with CASP14, mainly in that it created an "attention-based neural network system" that honed its previous capabilities to produce even more accuracy. Based on the results from CASP14, AlphaFold2 achieved an average score of

92.4 GDT in all categories, meaning that their margin of error was within the width of an atom. According to Moult, a prediction over 90 GDT is considered solving the problem of protein folding.

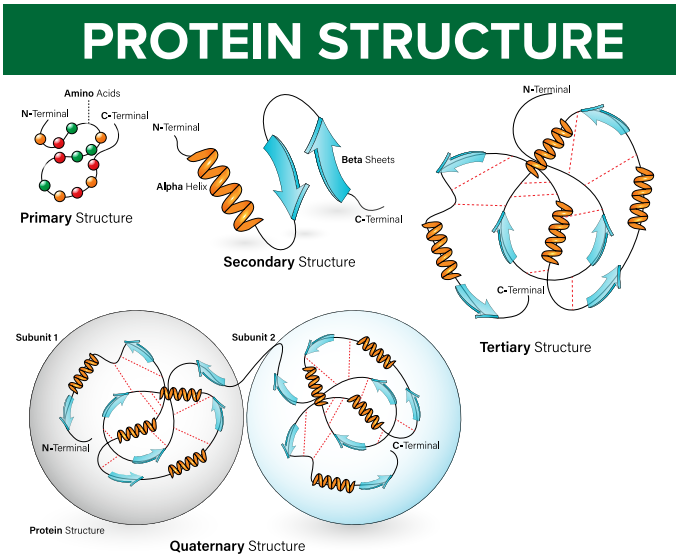
How does this work?

Christian Anfinsen developed the thermodynamic hypothesis in 1962, which illustrates that the unique linear sequence of amino acids dictates and undergoes folding to its native protein conformation because it is the most thermodynamically stable and favorable path given by its specific cellular environment. So, we know that there are forces acting within each level of protein structure to get to a state in which it is most stable and has the least free energy. The actual process and conditions necessary to obtain a conformationally stable three-dimensional structure from the sequence of amino acids alone is still being developed because the possibilities are infinite. Levinthal's paradox is a thought experiment that concluded that it would take longer the age of the existing universe to predict all possible conformations of a protein before even reaching the actual 3D structure of the protein. This is what constitutes what is known as the protein folding problem and has been riddling scientists for over 50 years.

As we know it, there are physical and chemical constraints within each structure of the protein that limit it to certain distances and angles between its component amino acid residues. A protein is a complex, biologically occurring molecule that is composed of tens to thousands of amino acids. As we know today, a protein can potentially have four levels to its structure. The primary level is its linear sequence of amino acids linked together by peptide bonds, and this level is limited to certain angles dictated by the peptide bonds. There are 20 naturally occurring amino acids that are found in the genetic code, each composed of a distinct R-group contributing to both the overall pH chemistry and structure of a protein. There are several intrinsic propensities of adjacent amino acid residues to arrange as alpha-helices or beta-sheets according to their structure and ionizable R-group identities. Tertiary structure includes all the interactions between R-groups of amino acid residues farther apart, and all aspects of overall folding that contribute to a protein's three-dimensional shape. Different portions of the polypeptide are held in place by weak non-covalent interactions such as hydrogen bonding, hydrophobic, van der Waals, ionic salt-bridge interactions, and covalent disulfide bridges. The large hydrophobic residues are arranged towards the center, or core, of the protein, while the ionizable amino acids are on the surface exterior, with likely-charged residues being repelled and structured accordingly. Proteins with more than two polypeptide chains combine together non-covalently to form a large complex of identical or distinct subunits known as quaternary structure. These constraints end up forming the overall 3D shape of the protein and its unique function. These rules can be used to generate our own models of proteins to create the most stable structure possible within the natural parameters.

There are three major neural models within AlphaFold: one to predict distances between amino acids, one for the torsion angles between these residues, and the last model to estimate the GDT of the predicted structure. AlphaFold is given access to the Protein Database, currently consisting of over 170,000 known structures of folded proteins so that it can analyze these known structures to identify patterns and similarities for known functions. These proteins are plotted onto a spatial cartesian graph to extrapolate the dimensional points (x, y, z) of its structure by analyzing where and how amino acids are positioned relative to other amino acids to promote optimal interaction. Multiple sequence alignment is a major component within the neural architecture of this process, in which several sequences of a protein from different species are analyzed to retrieve information about evolutionary covariation. This is used to determine which genes correspond with functionality. Memory-augmented simulated annealing is used between these models to test different dimensional predictions of a structure by comparing it to a set of acceptance criteria, like the known constraints and known proteins from the PDB [4]. The PDB

is also the basis of AlphaFold's GDT prediction. Trained with all this data, a machine learning algorithm plots out its predictions of protein structure by calculating the various interactions between amino acids and determining the conformations that need to be adopted to produce the most viable option. So AlphaFold's neural architecture solves two problems: How do you look to find the right solution, and how do you recognize you've got the right solution when you're there?



The Potential for AlphaFold

AlphaFold's neural architecture extracts information from data that it is fed, analyzes this data, and, most importantly, understands the conditions and folding mechanisms of the protein in question. It then uses all this information to create structures of proteins from the sequence of amino acids. The potential uses of AlphaFold are infinite. The most important use for AlphaFold is to predict the structure of proteins that are not yet known. The field of genetics certainly has a head start, having determined the sequences for over 180 million proteins. This is stark in comparison to the PDB, which only has about 170,000 protein structures. The main reason the PDB is so behind is because classical techniques such as X-ray crystallography and NMR can take months to years to generate a protein structure and tend to be very expensive. AlphaFold can make a huge contribution to the field of structural biology in that it can help determine the structures of thousands of unknown proteins in a matter of days.

Recently, with the COVID-19 pandemic, in an effort to hasten efforts in understanding the virus, researchers shared the genome of SARS-CoV-2 in a public database. AlphaFold fed this data into their program and were able to predict the structures of six unknown COVID-19 proteins. Two such proteins, ORF3a and ORF8, had their structures experimentally confirmed using Cryo-EM, and AlphaFold's predictions were pretty accurate. ORF8 was one of the proteins featured in CASP14, and its predicted model had an accuracy of 89.5 GDT. This is very promising as this is still an early model of AlphaFold, and it is already allowing us to determine proteins, which in turn allows us to understand their potential functions. There are many diseases, such as leishmaniasis and trypanosomiasis (sleeping sickness), for which there is little to no information about their protein structures. AlphaFold can help elucidate these structures to better understand such diseases and develop potential treatments. In fact, AlphaFold can improve the process of drug development and discovery as a whole. With research & development, clinical studies, human trials, and certification, the process of drug development can cost almost $2.87 billion and take over ten years to complete [11]. AlphaFold can fast track this process by identifying the structures of proteins involved in human diseases and their processes to efficiently target drugs to the correct places.

Misfolded proteins are another major source of human diseases. Genetic mutations can cause alterations in genes, disrupting and rearranging the sequence of amino acids of certain proteins. These misfolded proteins aggregate and accumulate in cells, causing diseases ranging from diabetes to Parkinson's and Alzheimer's. By having a prediction system that understands how a protein is folded, we can infer how the protein changes as a whole to ultimately understand the disease mechanism and find ways to promote proper folding. Along these lines, AlphaFold could also try to figure out how to best maintain the optimal shape of the protein over the long term. As we progress

in age, there is a steady loss of proteostasis, in which proteins start to malfunction as a result of changes in regulation with age leading to protein degradation, misfolding, and aggregation. By accumulating data about how protein structures can change over the years, we can possibly prolong the lifespan.

So far, AlphaFold can only determine static conformation and can predict the different subunits or peptides in quaternary structure, but it is not able to fully predict the interactions and ways the protein acts dynamically. In the future, AlphaFold should focus more on the quaternary aspect of protein structure. There are many proteins that weren't able to be structured either because their structure was too difficult to crystallize or were just simply too complex, possibly due to having multiple subunits. The clear interactions between peptide chains within a protein have yet to be conceptualized. By focusing more on the quaternary aspect, the true dynamic functional capabilities and interactions between complexes of proteins can be determined. Furthermore, the exact process and rules of how proteins are folded to achieve functional domains can be conceptualized.

Once the exact process of protein folding is determined, the possibilities are limitless. For example, one could code a particular sequence of amino acids to generate one's own functional proteins. Even new, non-naturally occurring amino acids could be synthesized to elicit novel functions in proteins. A universal vaccine could even be developed after identifying the various mechanisms in how viral proteins latch on to become pathogenic. For instance, we can make a vaccine with a protein molecule that expresses the different structural components of various strains of flu. This will ensure that our immune system is adapted to defend against various pathogenic mechanisms.

To go really science-fiction, we can potentially create proteins that act as machines for us. As we are exchanging fossil fuels in cars for electricity, can we possibly exchange carbon emissions for something cleaner and more efficient? Cellular respiration is one such process that comes to mind, having sustained life for over three billion years already. Climate change is rapidly deteriorating our planet. It is time to take this method of energy production and create new biological machines to replace the ones we use in our lives today that cause so much harm to the environment. We can create enzymes that break down toxic greenhouse gases and industrial wastes as fuel to generate another form of cleaner energy. New synthetic materials can even be made to limit the amount of waste we produce in the first place.

Deepmind's AlphaFold2 shows great promise and offers the beginning of the solution to the protein folding problem. Moreover, artificial intelligence and machine learning have proven to be of real value. However, there is still much more work to be done before a dynamic protein structure and its interactions are elucidated. It is important to reflect on the major technological advancements, in that they are all modeled after naturally occurring phenomena. The Wright brothers studied flying birds, honing in on how their wings changed shape to control different aspects of flight. These observations contributed to their designs of "wing warping" to control lift and roll, allowing for the first successful human flight. Edward Jenner developed the first vaccine for smallpox after observing that cowmaids and farmers were very healthy and resistant to smallpox compared to the rest of the population. AlphaFold was modeled after a human brain, in which attention-based neural architecture allowed for focused processing and computing all the scenarios a protein can be folded into, given the information it has learned. Nature is our greatest resource to learn more about the processes that govern life and to form tools with. We must all be in tune with nature so that we can form our own observations to advance our own lives.

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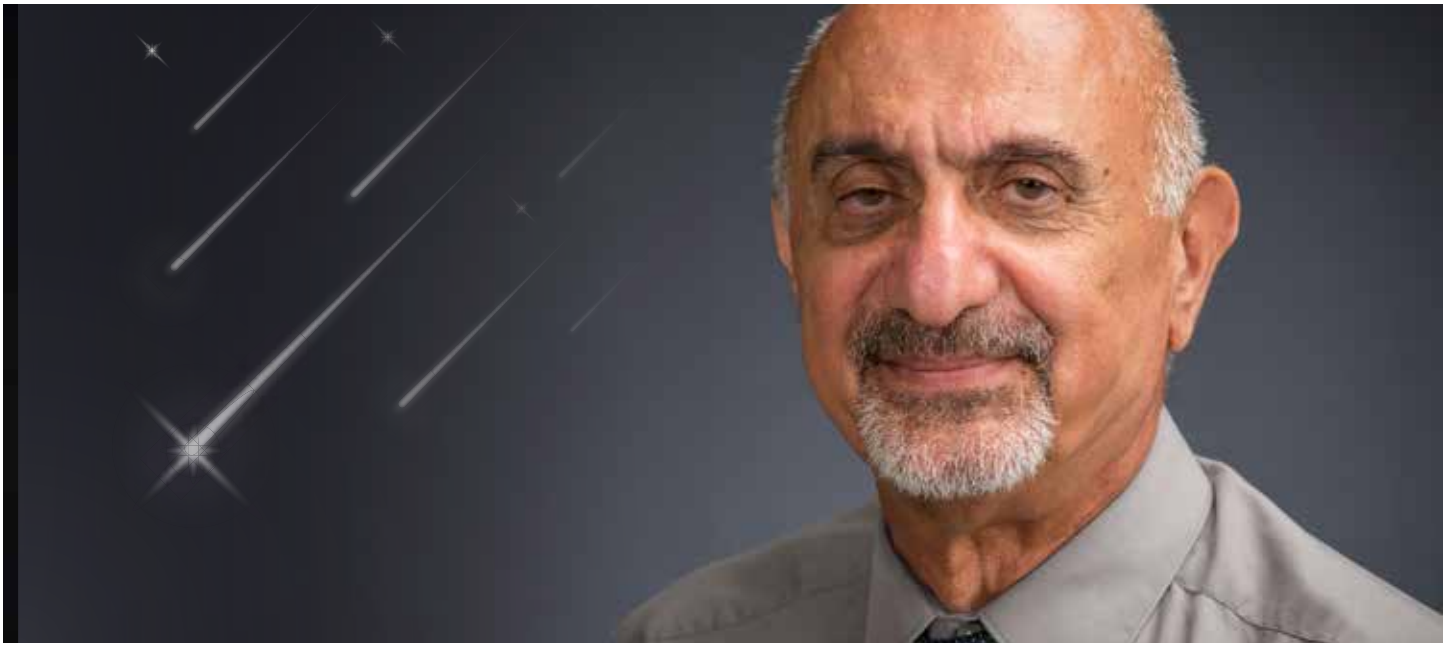
LIFETIME COMMITMENT TO SCIENCE AND STUDENTS

BY EMMA SCHULTZ-STACHNIK AND JULIA JONES



Pirooz “Paul” Mohazzabi is a professor of Physics in the Mathematics and Physics department here at the University of Wisconsin-Parkside. Dr. Mohazzabi joined the university in January of 1986, bringing with him ten years of prior experience as faculty of physics and engineering at other institutions in the U.S. and overseas. Dr. Mohazzabi received a Ph.D. Degree in Materials Science and Engineering from the University of California, Berkeley in 1975. After receiving his Ph.D., he realized that his true passion was Physics. Therefore, he pursued physics from then on. He has been teaching and publishing research articles in physics for over 43 years. He has nearly 100 research publications in international refereed journals, ranging from bicycle stability to cancer theory.

On a cold winter day, Emma and Julia (Jules) sat for this interview with Professor Mohazzabi in the midst of the COVID 19 pandemic. Below are the excerpts of the interview.

How would you describe the field of physics to someone without a background in science?
Math is the language of nature, physics is just nature.

What made you choose the field of physics?
I was initially in chemistry and then moved on to get my Ph.D. in materials science, which is when I discovered my passion was for physics.

What led you to want to study chemistry?
Well, I started wanting to do chemistry when I was 9 years old. It all started when I had a dream; a star fell from the sky into my backyard. I picked it up, it was beautiful. I asked my father what was in the star to make it glow. He responded: “phosphorus” (all of this in the dream). I have no idea where the word phosphorus was in my mind.

In the morning, I went to my father. I couldn’t tell what was real and what was the dream and asked him where I could get some phosphorus. He looked at me and said, “What do you want phosphorus for?” I said, “To make a star.” He

said, “Make a star? Are you crazy? You want to make a star out of phosphorus?” I said yes. He asked me where I had heard that from, and I insisted that he told me but he kept denying it, so I thought he was lying.

Of course, he never told me how to get phosphorus, but I had to somehow get my hands on it. So I started reading about it, and I read, and read… and I found out that animal bones have phosphorus in them, so I somehow had to get phosphorus out of animal bones. So I found out that you need to use chemistry to extract phosphorus from bones.

I began studying chemistry. My brother, who’s four years older than me, was studying chemistry in high school, so I read his books and realized I had to read more and I did. Eventually, I figured out how to do it. It took me almost 2 ½ years… In order to do it, I needed to obtain equipment and so on. Finally, I got everything to the last step, which was reducing metaphosphoric acid (a phosphorus compound).

I needed an electric oven that reached 1800 degrees Celsius. So I had to read more to figure out how I could make this oven. I needed a high melting point filament to build it. Where would I get that? I decided to break incandescent light bulbs to get the filament out of them because those were tungsten filaments. I broke a whole bunch of them, got the filament, and connected them in series and parallel. By then I knew how to do that. So then I built the furnace and ran it, but the filaments burnt out. Then I found out there should not be oxygen in the atmosphere when burning tungsten filament. When metals’ temperature reaches red hot, they start to oxidize and burn out. So then I managed to get some carbon dioxide to run through the furnace to keep oxygen out. So eventually, when I was 12, I managed to extract phosphorus from animal bones. That was the turning point in my life when I decided I wanted to study chemistry.

Did you make your star?
By then the point wasn’t even about the star, it was just seeing the phosphorus glowing at night in the oven. I just wanted something to glow at night without a battery. But by the time I was 12, I knew everything you needed to know about chemistry all the way through your bachelor’s degree. Even when I went to university, I never had to study chemistry because everything was so obvious to me. Finding reaction products was as easy for me as finding the bathroom.

What is your research interest?
Well, you (Jules) are working on asteroid impact and geomagnetic reversal, Emma is working on cold fusion. Then Gabby and Gwen and I just finished a paper, a model for a [coronavirus] pandemic. After this project, we’re going to work on the thermodynamics of hurricanes. And then I have a couple of other projects I’m working on, statistical mechanics of interacting molecules.

What is your favorite or most interesting research that you’ve done in your career?
There’s a couple that I thought were really good contributions. One of them was actually math. We found an interesting method of finding the limit of an infinite power series that has a very slow convergence. I did that with Tom Furnell, who’s now passed away. I thought that was interesting- even though the paper was published 20 years ago, every time I look at it or read it I enjoy it. And a couple of papers that I did in statistical physics that were interesting. The thing is, I never stay in one area. I’ve published papers ranging from bicycle stability to cancer theory. Obviously, everything was interesting to me, or else I wouldn’t have worked on them.

There is a pause and Paul starts dancing to music playing in the background
How’d you get so groovy? Was it going to UC Berkeley in the ’70s?
Probably, haha.

Do you remember anything noteworthy or inspiring from your college days? (late 60’s early 70’s)
Something that I never forgot was that when I was a freshman in college, I was taking calculus just like any other college student. And I remember once our instructor couldn’t come to the class for whatever reason, so they brought someone in to fill in for him. And this

guy was older, he was probably about 75 or 80 years old, and was a high school teacher. I remember that day was a turning point in my life in terms of math. That guy came and explained the concept of limits and derivatives. His explanation was so clear, vivid, and logical that it just turned my life around. At that point, I realized that I loved math just as much as I did chemistry. I just understood everything, it was so clear. I'll never forget that class. That was the best moment of my college education. Chemistry in college didn't mean much to me because I already knew everything that they were teaching me. But this explanation about derivatives and limits just made a huge difference to me. At that point, I decided I wanted to study math on my own.

When you teach calculus, do you use the same method as that teacher?

Oh yes, yes. In fact, the lecture notes I have are exactly the way he explained them.

At that point did you already know you wanted to be a teacher?

Oh yeah. I knew I wanted to be a teacher since I was 12 years old. And the reason was that when I managed to extract phosphorus from bone, my older brother told his high school teachers. They wanted to know how I made it, so the chemistry teachers came to my house. They wanted me to explain how I made it because the method I used was not in a textbook or anything. Just something I came up with. So these chemistry teachers were at my house (about 45 or 50 years old) listening to a 12-year-old kid explain how to extract phosphorus. That made me feel great. I always wanted to be a teacher after that.

If you weren't a physics professor right now, what do you think you'd be doing instead?

I would go back to school to learn physics so I could be a physics professor.

What is the best thing about being a physicist?

"The more you learn the more you realize how little you know."

What kind of stuff do you like to do besides teaching?

I like to fix cars. That's what I do when I get frustrated.

Do you ever break your car just to fix it?

Well I know it sounds crazy but yes I have done it... There were times where something was kind of working but sometimes acting up so I decided to just break it so I don't feel bad and then replace it.

Is that all you like to do? Don't you like dancing? ...*dances*

Since you first got into physics, have there been any significant changes in the field?

Well, of course. I mean there are things changing every day. I mean, not in classical physics of course, but in modern physics, elementary particles, the discovery of new particles. They're made every day.

Who do you think is the greatest physicist of the 19th and 20th century and why?

Well, that is kind of subjective, depending on whom you ask. I consider two in the 20th century, one is Einstein and the other is Richard Feynman.

Einstein had a deep understanding of the universe because he was looking into things very deeply. That's actually what he said, he said look deep into nature and then you understand things better... and, if you look at the laws of physics, think about different laws, let's say Kepler's laws of planetary motion, if Kepler had not discovered them, sooner or later somebody else would've discovered them, just like any other thing. Like superconductors, semiconductors, etc. Somebody would've discovered these things sooner or later. But if you look at the theory of general relativity, that's something that if Einstein had not discovered that, I don't think, it would've been discovered even today because it's not something obvious, it's extremely deep and convoluted. I don't think anyone else would've discovered this for even many many years to come.

What about Feynman?

When you look at physicists, generally they are very good at a specific area...

Well, Feynman, he was not just working in one area he was working in every area that you can imagine...and when he got the Nobel prize, he didn't get it for one specific work, he got it for general contribution to every area of physics. And I told you that I met him once, it was

interesting. What I remember was that, when he spoke, he was frightening. Because look, suppose that you want to make a statement to present something. Very simple things like, okay I went to the mall this morning and I saw this thing in the shop. When he said a sentence, you could take the words that were used in the sentence and then you could try to find a better way of expressing the same idea, with a smaller number of words, like more efficiently, you couldn't! It was the best way that you could combine these words together to express the idea. It's like a computer, you know crunched through the words and then came up with the optimum way of making a sentence. It was just frightening when you listened to him.
We just went to get his signature on a book, his autograph, but he came and sat down with us.

When was that?
I want to say 1974.

What do you think about the field of physics 50 years from now?
Beats me, I have no idea. Probably some of the things that we've discovered lately are going to be proved wrong.

Really?
Yeah, those things happen all the time, and that's why one has to look at these things with an open mind.

Do you think the theory of Special Relativity will ever be disproven?
I don't think it would be proven to be wrong because there is overwhelming evidence of the results of special relativity. But accuracy is a different thing. Some of the results might not be as accurate as we think they are. Might be you need to be revised or something. But again, you never know

Do you think in the next 50 years we will make the connection between quantum and special relativity?
Well, those things are already connected. The main thing is something that I have always been curious about, is not whether some of the things that we know are correct or not?
The main thing is are these laws of physics, the way that we have discovered them here, are they applicable somewhere else in the universe? For example, we know that for an object to move in a circle you need centripetal force, but then, is that true let's say, somewhere in a universe one million light-years away from us?

I mean everything, the laws of electromagnetism, the laws of mechanics, and so on, are they valid everywhere in the universe? We already know that when you go from small dimensions to elementary particles the laws of classical physics are not applicable anymore, right? You need quantum mechanics. Or, when you go to large dimensions, not just the laws of physics, but even our Euclidean geometry breaks down. For example, the sum of the angles of a triangle, if the dimensions are really large, is always bigger than 180 degrees. So when we already know these things, how can we be sure that all the laws of physics the way we discovered them in our solar system, how do we know that they are always valid? I'm not saying they are not valid, but I'm saying that one has to look at these things with an open mind, just in case.

Do you have any advice for people who are just beginning their careers in physics?
Physics is something you have to be interested in to get into it. It's not a field that you pick so you make a lot of money. It's just something you have to enjoy doing. You have to be interested in nature, learning how nature works. That's what makes you a physicist.

You know by training I'm not a physicist, right? I'm a materials scientist, my Ph.D. is in materials science. Physics is something I taught myself.

Well, how do you do that?
Well, just by reading books and thinking about problems. Right? It's not hard.
If you are interested in something you're learning- no matter what it is- if you're interested in it, if you like it, you learn it. The learning of that material comes easily. If you're not interested, no matter how hard you try, you can't learn it.

How long did it take to teach yourself physics?
It's an ongoing process, I'm still not done.

Could you give us a brief explanation of how the physics program was at Parkside when you first started working here?

They hired me because there was a faculty from the physics department who started teaching the engineering classes, so they needed someone to replace him. When I got here there were only three faculty in the department including me. And two lecturers. Shortly after, it dropped down to two faculty and one lecturer. In the mid-'90s, there was an increase in students in the physics department, we had something like 25 students. Then it dropped again and in 2014 there was only one physics student, Siva. Then it came back up again and in 2019 we had about 30 physics students. That is not the main point. It doesn't matter how many students are in the department, the only thing that matters is when they graduate, they are prepared. They can go to graduate school and be successful. What's the point in graduating 50 students a year if they don't know anything?

What accomplishment are you most proud of?

Accomplishment? I don't think I've accomplished anything.

What about all the papers you've written?

Well, that comes with the profession. It's not a big deal.

You've certainly turned the Parkside physics department around, don't you think? Don't you consider that an accomplishment?

Well, I tried to do my best. Let's put it this way: If you do something for your family, would you consider that an accomplishment? I mean, this community is my family. You know that. My students are like my family, so if I do something for them, I don't consider it an accomplishment. It's just helping my family. Do you see what I'm saying?

What is the best approach to get more people into this field?

You cannot get people interested in something, either you like something or you don't. They have to experience something and decide for themselves if they like it or not. Like I can't do anything to make you like milk chocolate. All I can do is give you some and let you taste it and then you decide whether you like it or not. And that is what we are doing. As a physicist I show my students what physics is, they are the ones who have to decide.

EXERCISE: THE MIRACLE PILL

BY ALEXANDER LOVELY AND KATIE WILSON

If the benefits of exercise could be aggregated and fashioned in the form of a pill, it would be the best-selling prescription in history. Everyone is aware that physical activity can 'help you lose weight,' but the scientific literature is detailing that the advantages of exercise expand much beyond losing a couple of pounds. Not only does exercise address physical health to a profound degree, but it also benefits cognitive competency and affective aspects. Movement is a daily necessity for overall health and well-being.

PHYSICAL DOMAIN

As advancements in technology provide for more sedentary occupations and recreational activities (video games, social media, streaming services, TV, etc.), obesity in America has reached epidemic status. One in three adults as well as 15-20% of children and adolescents in America meet the criteria for obesity. Associated with obesity are many health risks and diseases including type 2 diabetes, heart disease, sleep apnea, hypertension, many forms of cancer, and the list go on. Physical activity helps combat all these conditions. Exercise strengthens the heart and improves circulation, which elevates oxygen content in the body. This can have an effect in lowering the risk for cardiovascular-related diseases as well as mitigate high cholesterol and triglyceride levels. In addition, exercise can reduce blood sugar levels and affect the efficacy of insulin, improving the functioning of the endocrine system.

COGNITIVE/MENTAL DOMAIN

In a world where everyone has limitless access to information and entertainment in their pocket, distractions are constant. As a result, conditions such as attention deficit hyperactivity disorder (ADHD) have reached peak prevalence. The symptoms of ADHD include difficulty concentrating and focusing, being forgetful about completing tasks and being easily distracted. For obvious reasons, these indications pose a barrier to an individual's optimal functioning in modern society. Physical activity facilitates the release of several neurotransmitters including dopamine, serotonin, and norepinephrine, which play a role in mental acuity, concentration, memory, and motivation. In addition, exercise stimulates the production and release of brain-derived neurotrophic factor (BDNF), which functions in the growth, maturation, and maintenance of neurons. Exercise quite literally can make a person smarter.

AFFECTIVE DOMAIN

As the incidence rate of the physical disease has increased in recent years, the phenomenon has been accompanied by mental disorders. Approximately one in four Americans suffer from a variant of anxiety and/or major depressive disorder. In terms of treatment for these conditions, medication is commonly prescribed, however, this route can prompt side effects as well as addiction (depending on the medication). Cognitive-behavioral therapy is also employed to treat mental disorders and has been shown to be an effective strategy. Exercise can serve an influential role in treatment as well. During physical activity, chemicals such as endorphins, GABA, and serotonin are released that improve mood and relaxation; helping alleviate stress. Exercise has even been shown to be more efficacious than

selective serotonin reuptake inhibitors (SSRIs) in the case of treating depression.

The Physiology of Exercise

The brain connects to the muscles through nerves that are huge contributors to physical activity. While only taking up 3% of our total body weight, the nervous system is the reason we are able to exercise. One of the most complex systems in the human body, it delivers signals for our basic functions, like regulating organs and controlling muscle movements. Adriaan Louw, a physical therapist, neuroscience researcher, and the author states that "After approximately 10 minutes of moderate aerobic exercise, the brain produces more of a calming effect on nerves. Pumping blood and oxygen around nerves also calm them down" (Louw, 2013).

Nerves are not the only thing connected to a muscle. Blood vessels also play a role. For each muscle fiber, there is at least one capillary bringing in oxygen and nutrients while removing the waste products that come from the metabolism of muscles. These capillaries bring in oxygen-rich blood to the working muscles while exercising. While the body is supplying this oxygen-rich blood to these muscles, blood flow to other organs that are not essential during exercise is reduced. This is why heart rate increases, breathing rate elevates, sweating occurs, and many other bodily functions are turned down for the duration of physical activity.

There is a multitude of reasons why individuals don't exercise. Many people are hesitant to work out because they don't know what to do or where to start. Exercise does not have to be rigorous for it to have positive effects on the body and overall well-being of an individual. Taking one hour out of your day to go for a walk can make all the difference. Walking for one hour can benefit your brain, lungs, muscles, bones, joints, heart, and much more. Simply going for a walk multiple times a week can yield the following benefits, among others: aiding in digestion by enhancing gastric motility and eliminating toxins, promoting colon health; reducing the risk of stroke by >30%, heart attack by 50% for middle-aged people, type 2 diabetes by 60%; preventing muscles from deteriorating; increasing bone density; replenishing synovial fluid in the joints; and improving attention, memory, awareness and motor skills.

Get out and exercise!

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WHAT'S SO SUPER ABOUT SUPERCONDUCTIVITY?

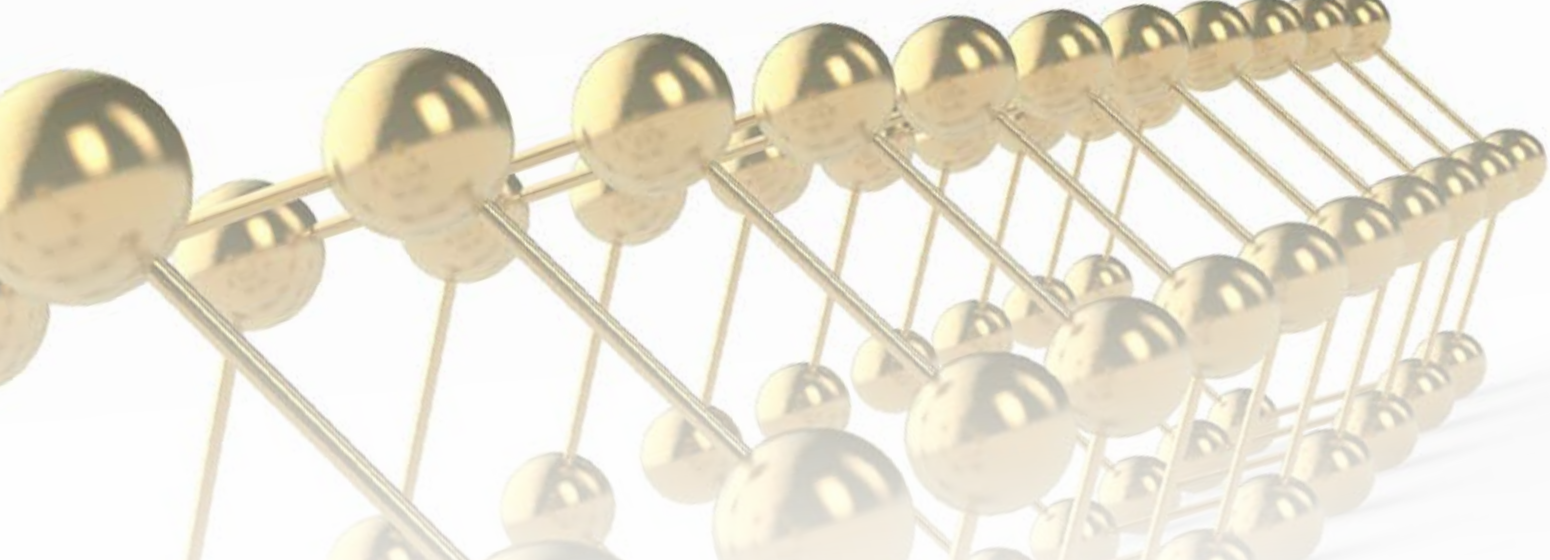
BY JULIA JONES AND HOM KANDEL

Superconductors are materials that conduct electricity without electrical resistance. This means that, unlike the more familiar conductors such as copper, a superconductor can carry a current indefinitely without losing any energy. A resistance-free current (i.e., flowing in a wire) is one of the three trademarks of superconductivity, and this characteristic plays a crucial role in the exciting implications of these materials. Scientists working in the field of superconductivity are developing and experimenting with new technologies while simultaneously broadening our knowledge of the basic physics behind superconductivity. Research on this topic can lead to more efficient and reproducible superconductor-based devices-- and these devices are used in our daily lives more than we think.

Superconductors are prevalent in many areas of modern technology and are a hot topic in Condensed Matter Physics, Materials Science and Engineering, and Applied Physics. One example is the efficient transmission of power over electric grids around the world. The U.S. Energy Information Administration (EIA) estimates that about six percent of electricity generated in the U.S. is lost between the power plant and its destination due to resistance in normal conductors. Superconductors, on the other hand, are 100% efficient, which means superconductivity allows us to come up with more effective solutions regarding the transmission of the power. It doesn't stop there though, superconductors are used in a number of ways: in medical imaging (MRI), very high-speed magnetic levitation trains, particle accelerators, electric motors, and Josephson junction devices.

Superconductivity is a macroscopic phenomenon first observed in 1911 when Heike Kamerling Onnes submerged a mercury wire into liquid helium and found that the resistivity of the wires dropped to zero. This was the first discovery of superconductors, so-called type I superconductors, and it opened the doors for many discoveries to come. In 1957, Bardeen, Cooper, and Schrieffer came up with a classical model of superconductivity, known as the BCS theory, which describes the mechanisms behind type I superconductors. They described superconductivity as a macroscopic effect caused by a condensation of Cooper pairs. These pairs can be defined as a loosely bound pair of electrons moving with the same speed in opposite directions and with opposite spins. Above the critical temperature, repulsive behavior occurs between two electrons; below this temperature, the behavior becomes attractive to some degree. Two electrons "team up" even though they both have a negative charge which would normally repel each other. Paired electrons form a Bose-Einstein condensate- a macroscopically occupied single quantum state- which flows without resistance; this behavior of the condensate is a key component to superconductivity.

Something important to note is that superconductivity exists only within limited values of temperature, current density, and magnetic field. Beyond a certain value of these quantities, superconductivity is destroyed and the material retains the normal state. Hence, for a material to exhibit superconducting properties, certain conditions must be satisfied. The highest temperature at which superconductivity occurs in a material is called



the critical temperature (Tc). Below the critical temperature, the resistivity of the material is equal to zero, and all other corresponding phenomena associated with superconductivity become present. However, we must keep other factors in mind. For example, even below the critical temperature, there is a maximum value of electrical current per unit of cross-sectional area, called the critical current density (Jc), that a superconductor can carry without resistance. If an electric current above Jc or magnetic field above Hc is applied, the superconducting property of the material is lost.

One of the most important breakthroughs in superconductivity is the discovery of high-temperature superconductors in 1986 by George Bednorz and K. Alex Müller at the IBM Research Laboratory in Zurich, Switzerland. These superconductors have critical temperatures higher than type I superconductors and do not obey the BCS theory of superconductivity. Moreover, they do not need to be cooled to the low temperature of liquid helium to exhibit superconducting properties, which eliminates the issue of expensive and complex cryogenic systems and obtaining rare helium itself. This revelation awarded Bednorz and Müller a Nobel Prize in Physics, and extended the boundaries of superconductivity, creating opportunities for new research that continues to this day. One of the most popular high-temperature superconductors is YBCO (also called “IBKO” or simply Y-B-C-O), whose critical temperature value is 93K, much higher than the boiling point temperature of the liquid nitrogen (77K). Additionally, high-temperature superconductors have higher values for critical current and critical magnetic field, which means they are more efficient and can be used in a larger span of applications.

Josephson junctions, discovered by Brian Josephson in 1962, are one noteworthy application of superconductors. They are nanoelectronic devices created by sandwiching an extremely thin layer of non-superconducting material between two layers of superconducting material. What’s groundbreaking about these devices is that electric current can flow through the junction even in the absence of an electric voltage or current source. They are used in SQUID biomagnetometer sensors, qubits, rapid single flux quantum RSFQ circuits, and terahertz frequency detectors, for a wide range of applications including Magnetocardiography (MCG) & brain imaging used in medical facilities, quantum computing, geophysical measurements, and NASA & military (TSA/ airport security) purposes.

Josephson junctions operate based on the fact that under the critical current, pairs of electrons “tunnel” through the insulator barrier from one superconductor to another, without any resistance. On the other hand, if the critical current is exceeded, an AC voltage develops, which is dependent on time and oscillates. Many systems with Josephson junction devices detect and measure the change from one state to the other, utilizing this oscillation for their applications.

These devices are made using a nanofabrication technique that requires complex thin film deposition and patterning using lithography. One of the most difficult aspects is that the non-superconducting layer

must be very thin, sometimes even down to a few nanometers. This layer can be an insulator or a non-superconducting metal, depending on the type of junction.

One of the latest challenges scientists are facing in this field is developing a high-temperature superconductor-based Josephson junction device, which offers many advantages over the conventional low-Tc superconductor-based devices already on the market. The benefits of high-temperature-based junctions are similar to the benefits of high-temperature superconductors including system simplicity, higher efficiency, and low-cost production. Here at the University of Wisconsin-Parkside, our research group, led by Professor Hom Kandel, is working in collaboration with other universities and national laboratories to fabricate such a device, using YBCO as the superconductor and PBCGO as the insulator.

Superconductivity has been studied for a little over 100 years; the restrictions that scientists once thought all superconductors were bound by have been expanded, but there is still much work left to be done. The scientific community has only scratched the surface of this phenomenon, and by gaining a deeper understanding of superconductivity and the process behind it, we can work to improve the technology and development of superconductors-- and fully reap the societal benefits that will follow.

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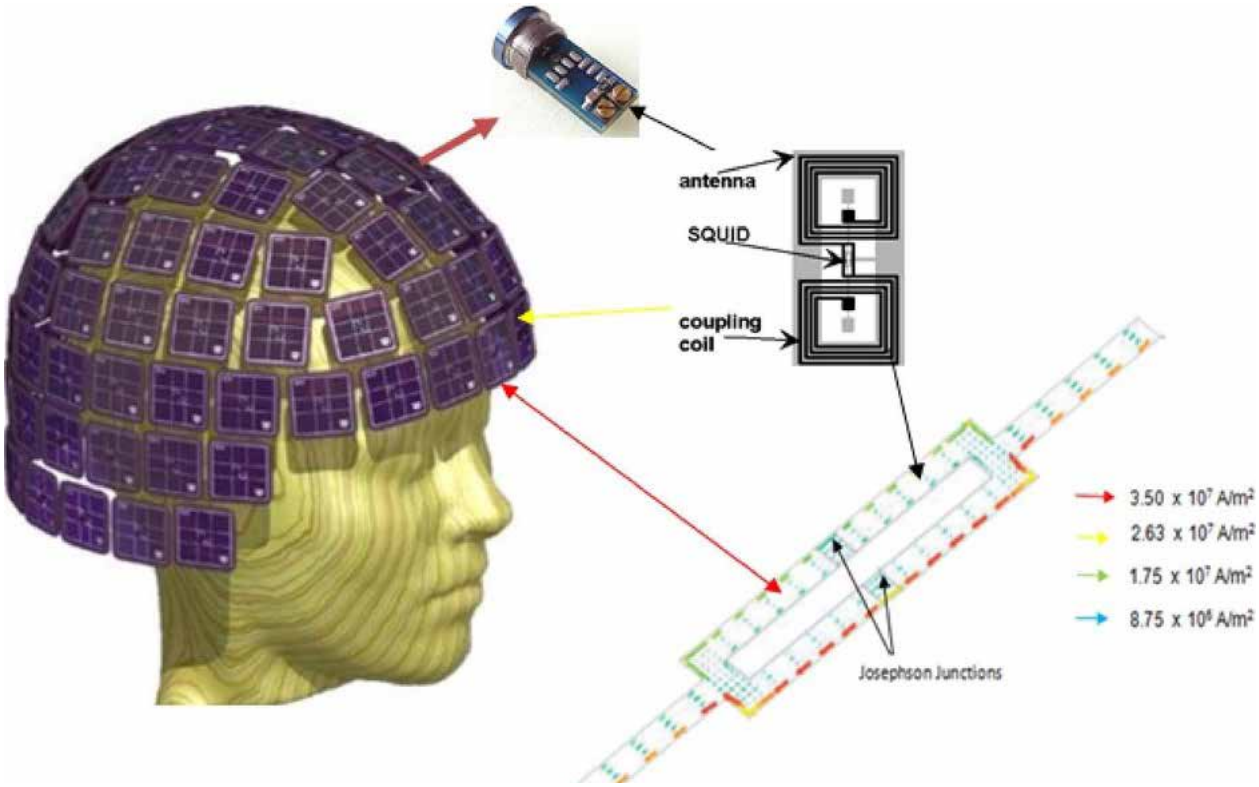

THE PROBLEM OF CLIMATE CHANGE

BY GENY MUSEITEF

The problem of climate change is enormous and its effects are devastating, making it one of the critical challenges of modern times (Rosenthal & Watson, 2011). According to the World Economic Forum's 2016 Global Risks Report, failure to mitigate climate change can be the most impactful risk that communities will face across the world. Climate change is a global problem with more devastating impacts than weapons of mass destruction. For example, climate change can transform global ecosystems, and affects everything including plants, animals, and people. The effects can be evidenced in the air, water, and soil, with the main cause of climate change being global warming.

The trends in global warming evidenced in the 20th century are attributed to the human expansion of the "greenhouse effect," warming that results from trapped heat (Rosenthal & Watson, 2011). The atmosphere traps heat radiating from the earth towards space. Gases known as greenhouse gases block heat from escaping, hence increasing the earth's temperature and resulting in global warming. The most common gases associated with climate change include carbon dioxide, nitrogen oxide, water vapor, and methane, with carbon dioxide being the main cause of greenhouse effects. Research indicates that carbon dioxide causes 80% of global warming, centering the focus on carbon emission.

Based on these findings, experts are focused on synthesizing crucial polymers that will release no carbon. This research seeks to propose ways through which polymers can be synthesized (Rosenthal & Watson, 2011). Based on the statistics and the findings of the World Meteorological Organization's (WMO), carbon dioxide is the single most important greenhouse gas emitted through human activities. This occurs through burning of fossil fuels and deforestation. The devastating impact of carbon dioxide on global heat is a huge cause of concern (Xing & Liu, 2018). The WMO argues that since the beginning of the industrial era in 1750, the average concentration of CO2 in the atmosphere has consistently exceeded the 400 parts per million threshold. Between 1990 and 2012, a more than 32% increase in radiation resulted in a warming effect in our climate due to the greenhouse gases.

As the rate of carbon dioxide concentration continues to rise, so do climatic concerns. While plastic or polymers contribute immensely to global warming due to the burning of fossil fuels, they play an important role in modern society. The continued combustion of fossil fuels increases the concentration of CO2 and this poses a huge challenge to the climate. Consequently, there is a need to devise means through which polymers can be synthesized without contributing to carbon dioxide emissions (Xing & Liu, 2018). Research indicates that by adopting bioplastic technology, deriving plastic from CO2, and using other forms of improvisation, the amount of fossil fuels used can be reduced, resulting in a positive impact on greenhouse gas emissions (Changwichan et al., 2018).

Bioplastics Production

Bioplastics production is one of the main ways through which polymers can be synthesized in a manner that does not contribute to global warming or the greenhouse effects (Changwichan et al., 2018). It not only reduces the amount of fossil fuels in the atmosphere, but it also has a positive impact on climate change by lowering greenhouse gas emissions. There has been tremendous interest in the production of bioplastics such as polylactide (PLA), disposable cutlery made from bottles fashioned from corn, potatoes and food wastes. Research indicates that polyhydroxyalkanoates (PHAs), polylactic acid (PLA), and polybutylene succinate (PBS) are the most promising biodegradable and bio-based plastics. The flexibility of PLA, PHAs, and PBS has the potential to replace conventional plastic and reduce carbon emission. Critics and experts believe that for bioplastics to be practically viable, environmental impact analyses must be conducted. However, other variables such as social and economic impacts should also be taken into consideration. Consequently, cost-benefit analysis is another important step that must be taken into consideration as well (Changwichan et al., 2018).

The environmental and economic sustainability of bioplastics are the most important variables in this perspective, but the downside of bioplastics is that they do not biodegrade as fast and easily as possible, sometimes requiring industrial composters to biodegrade. Another challenge is the energy needed to produce them, which can be enormous, showing that there is a need to enhance sustainability of biolistic (Changwichan et al., 2018). While there is a need to reduce burning of fossil fuels, this process should be done in a sustainable, practical, and cost-effective manner. These factors indicate that bioplastic production as a means to curb production of greenhouse gases is still a work in progress, which once perfected will have a tremendous impact in solving the problem of climate change. For that reason, more research is needed in this area to enhance efficiency and effectiveness means of carbon emissions.

Making Plastic from CO2

Plastic wastes have gained attention in the climate change debate and are attributed to the increase of global warming due to the emission of carbon fuels. However, what has been hugely ignored is how the process of making plastic contributes to carbon emissions. The concentration has always been on the lack of biodegradability of plastic itself as opposed to the process of making plastics. Research indicates that while plastics have

a large carbon footprint, the same applies to possible alternatives, making this a problem without a clear solution. The real problem of plastic begins at the wellheads where it comes out of the ground- the initial phase of plastic production. Carbon emissions occur at this stage of plastic production, as there are gas leaks occurring at the wellheads where plastics are produced. The chemical process to turn gas or oil to plastic emits gases which contribute to pollution. Additionally, factories use a lot of energy in the production of plastics and generate more emissions. Thus, the cycle continues, leading to more emissions of fossil fuels into the atmosphere.

The production of plastic from CO2 is viewed as an alternative to the conventional process of plastic production and is an environmentally friendly process. During this process, instead of using fossil fuels to produce plastic, the process is reversed and CO2 is used instead. The carbon dioxide used in this case is from hydrogen production, and the process is expected to immensely reduce burning of fossil fuels. The most important result of this process is its contribution to the solution of the problem of climate change by lowering emission of greenhouse gases (Joyce, 2019). Researchers have come up with ways to make polyacrylamide from carbon dioxide, an important breakthrough in this field. The secret to making plastics from CO2 lies on designing a sophisticated catalyst – materials that speed up chemical reactions with epoxides in the production of polymers, forming the basis for production of polyurethane-material present in cushions, refrigerators, mattresses and other plastic materials (Joyce, 2019). The process would present an ideal alternative to the conventional plastic production process, and present opportunities to curb global warming and the associated climate change.

The Alternative Raw Materials

Plastics are used in the manufacture of a broad range of materials, tools, and equipment, so looking at alternative raw materials would help reduce carbon emissions. The process of plastic (polymer) production involves carbon emissions, so an alternative raw material can help curb the increasing emissions of CO2. Statistics indicate that more than 15 million tons of polyurethane are produced annually, so changing to carbon dioxide feedback can have a tremendous impact. For example, foam products are made from polyurethane, but this can be alternatively produced by carbon dioxide. In the U.K, Econic is producing polyurethane from CO2 instead of using the conventional plastic materials (Orgilés-Calpena et al., 2016). The same is used in the production of seal-ons, elastomer, and coatings. Research evidence indicates that these materials match the quality of conventional plastics, and in some instances even exceed them (Orgilés-Calpena et al., 2016). While the production of carbon dioxide from plastics appears highly ambitious, it should be embraced as one of the most important interventions against carbon emissions.

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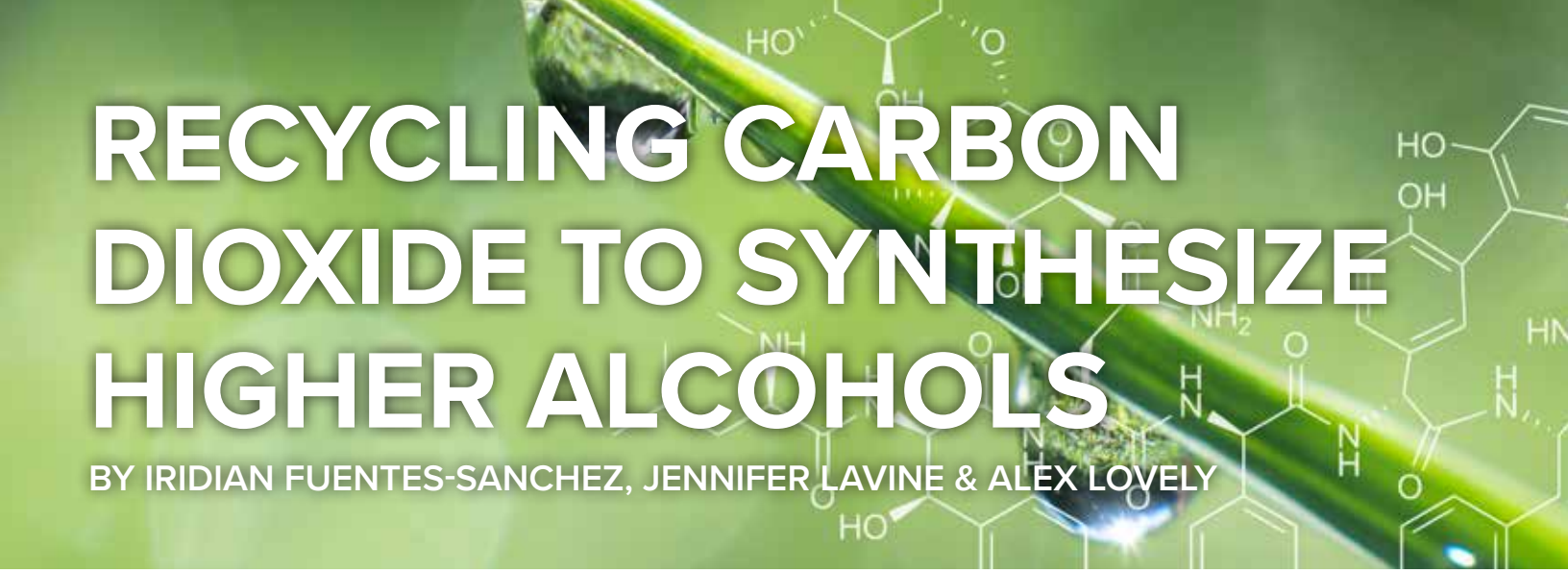


RECYCLING CARBON DIOXIDE TO SYNTHESIZE HIGHER ALCOHOLS

BY IRIDIAN FUENTES-SANCHEZ, JENNIFER LAVINE & ALEX LOVELY

Atmospheric carbon dioxide levels have peaked within the most recent century and are registering the highest recordings in 400,000 years (Luthi, 2020). In 2013, carbon dioxide levels surpassed 400 ppm for the first time in documented history. These statistics will continue to escalate as mankind's relationship with fossil fuel burning to generate energy is ongoing.

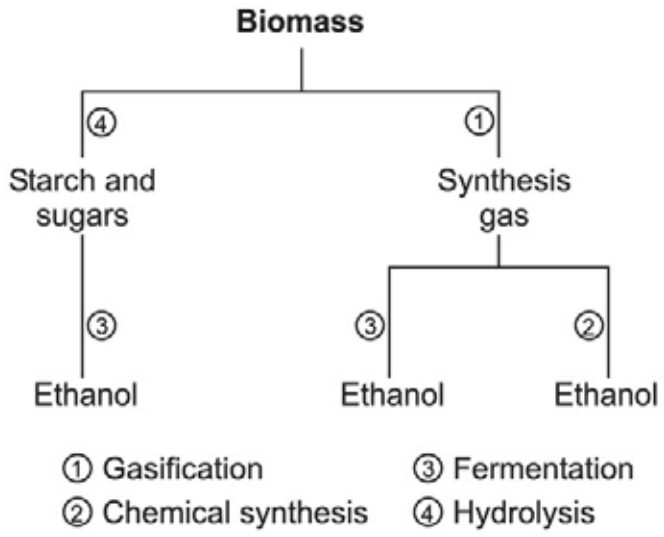
As carbon dioxide accumulates in the atmosphere, the global temperature displays a correlational increase, producing many devastating implications. A critical repercussion is that sea levels begin to rise as polar ice caps and glaciers begin to melt (National Oceanic and Atmospheric Administration, 2019). The influx of water impacts regions as floods occur, consequently contaminating water quality. It also puts coastal zones at greater risk of erosion and storm surge. In addition, the global food supply relies on weather conditions and climate to be within a certain range/predictability. Although it is adaptable to some degree, vastly increased temperature changes and water stresses create challenges to sustain agriculture. Marine life is also being affected. The ocean absorbs approximately 30% of the carbon dioxide that is released into the atmosphere (from burning fossil fuels), and with the consistently increasing concentration, oceans are becoming more acidic .

The accrual of atmospheric carbon dioxide generates many insinuations pertaining to water, food, health, and the environment in its entirety. Much research is being put into industrial-scale practices that aim to level and reverse this accumulation. One way we have attempted to combat this trend is through adding ethanol and other alcohols to our domestically produced transportation fuel. Not only are these alcohols renewable, but they decrease the amount of petroleum consumed, thus reducing emissions (U.S. Department of Energy, 2020). The carbon dioxide discharged via operating a vehicle when ethanol is burned is offset by the carbon dioxide captured when the feedstock crops are farmed to produce ethanol. This differs from gasoline and diesel (refined petroleum products extracted from the earth); no emissions are offset when these mediums are burned. On a life cycle analysis basis, greenhouse gas emissions are reduced 34% (on average) with corn-based ethanol produced from dry mills, and range between 88% and 108% with cellulosic feedstocks utilization (depending on feedstock type) compared with gasoline and diesel usage and production .

Although ethanol serves as a relatively bio-friendly substance that helps reduce emissions (including atmospheric carbon dioxide), higher alcohols have several advantages over ethanol. Not only does their composition house higher energy density, they also possess lower hygroscopicity properties (tendency to absorb moisture from the air) as well as low vapor pressure; both of which lead to better air quality (Liao, 2010). However, naturally occurring microorganisms don't produce them. Much gratitude is owed to the hard work and

ingenuity of Dr. James Liao, who has developed genetically engineered microorganisms to produce higher alcohols from glucose or directly from carbon dioxide. His technology is revolutionary and until now, alcohols of this kind have never been synthesized directly from carbon dioxide.

The traditional methods of farming alcohols utilized in transportation fuel and other large-scale chemical feedstocks include harvesting ethanol via fermenting biological material as well as chemical synthesis.



The more widely used of the two operations is the biological fermentation of sugars, which converts carbohydrates into an aqueous solution of ethanol via a process coined dry milling (see figure 1). The procedure is initiated by grinding the biomass (source varies on the region; the US primarily uses corn) containing the starch flour then implementing a method to release the starch from the meal. This can be accomplished through several routes, one of which being to mix the meal with water to create a slurry (the mash) and heat this mixture to ca 400 K under pressure. The enzymes a-amylase and glucoamylase can be added to the mash at a lower temperature as an alternative technique to extract the starch molecules. The mash is then transferred to heated fermenting tanks (360 K) and a-amylase, an enzyme that aids in the breakdown of the starch into simpler sugars, is added.

$$2(C_6H_{10}O_5)_n + nH_2O \longrightarrow \underset{\text{maltose}}{nC_{12}H_{22}O_{11}}$$

The mash is then cooled by 10 K (to 350 K) and a-amyloglucosidase, an enzyme that facilitates hydrolyzation of the carbohydrate into glucose, is added.

$$C_{12}H_{22}O_{11} + H_2O \longrightarrow \underset{\text{glucose}}{2C_6H_{12}O_6}$$

After the mixture's content has been converted to glucose, it is further cooled to 310 K, and live yeast is added. This action ferments the glucose into an aqueous solution of ethanol and carbon dioxide.

$$C_6H_{12}O_6 \longrightarrow \underset{\text{ethanol}}{2C_2H_5OH} + 2CO_2$$

The final procedural element concludes two to three days, during which the mash is stirred and idles at ca 310 K. The yeast is eliminated by the ethanol concentration. After distillation, the concentration of ethanol yield maxes at 96% due to the formation of an azeotrope. Pure ethanol is then obtained through a molecular sieve procedure, which operates by collecting the water molecules.

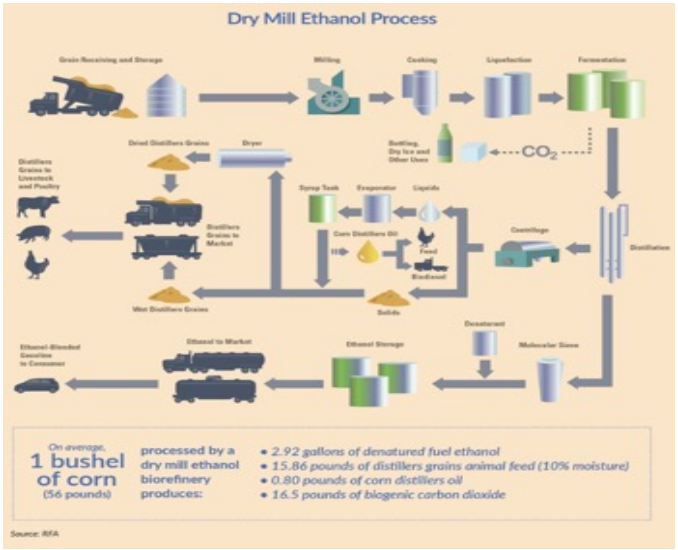


Figure 1

An alternative way of harvesting ethanol is through a thermochemical conversion of the involved biomass utilizing gasification (The Essential Chemical Industry – Online, 2020). This process synthesizes a gas comprised of carbon monoxide and hydrogen (coined syngas) whose designed ratio remains constant in terms of additional components and contaminants including sulfur, tars, and

other solids. Because of the flexibility of this procedure, in principle, any biomass including feces could be advantageous in producing syngas. The gasification relies on high heat (1600-1800 K) in a stream of oxygen or steam and whose product can be converted into useable fuels including hydrogen, methanol, and ethanol. The syngas is converted to ethanol via the Fischer-Tropsch process.

$$nCO + 2nH_2 \longrightarrow (CH_2)_n + nH_2O$$

As alluded to earlier, Dr. James Liao has developed an efficient technique to yield higher alcohols (molecules not naturally occurring in microorganisms) in a way that capitalizes on both more energy and less waste. In 2010, he was awarded the Presidential Green Chemistry Challenge Academic Award (Environmental Protection Agency) for his discovery. In summation, the technique utilizes microbial technology to produce alcohols comprised of three to eight carbons (higher energy alcohols) directly from carbon dioxide. Dr. James Liao genetically engineered a photosynthetic microorganism, Synechococcus elongatus PCC7942, and through overexpression of ribose 1,5 biphosphate caroxlyase/oxygenase (Rubisco), increased production of isobutanol (along with isobutyaldehyde). The highly active amino acid biosynthetic pathway was complexed and manipulated to divert its 2-keto acid intermediates into alcohols. With high efficiency and specificity, Dr. Liao's system has produced isobutanol from glucose in near-theoretical yields. In addition, the bioengineered strain produces isobutanol at a higher rate than those reported for ethanol, hydrogen, or lipid production via cyanobacteria or algae as well as the current rate of ethanol harvested from corn (Laio, 2010).

This method used to harvest higher alcohols implements several aspects of green chemistry, one of which being pollution prevention. Similar to ethanol, higher alcohols are inserted within transportation fuels and chemical feedstocks to reduce emissions by decreasing petroleum concentration. However, the methods utilized to yield both products differ in their carbon footprint. Dry milling of ethanol only offsets the carbon dioxide it releases (from combustion engines in vehicles) when carbon dioxide is consumed during the growing process. In comparison, Dr. Laio's biosynthesis directly converts carbon dioxide into applicable alcohols, overall reducing net emissions. In addition, the use of higher alcohols versus ethanol in terms of fuel substitutes employs higher energy density, lower hygroscopicity, and lower vapor pressure; the latter two leading to better air quality.

Another green chemistry characteristic Dr. Liao's biosynthesis exhibits are energy efficiency. This system converts carbon dioxide into higher alcohols yielding not only higher energy content, but also produces said alcohols at a faster rate than the traditional dry milling procedure of ethanol. The biosynthesis technique employs the direct conversion (of carbon dioxide to higher alcohols) rather than the implementation of several modifications of physical and chemical processes. By bypassing the additional stages of growing, collecting, then deconstruction of the biomass, treating it with multiple enzymes (after several conformations) to produce the desired product, and omitting the function of live yeast, efficiency is improved as well as addresses the green chemistry principles of atom economy and reducing derivatives.

Elevated carbon dioxide levels and global climate change have stimulated efforts to reduce emissions. One approach to addressing this problem is to recycle carbon dioxide directly into higher alcohols using photosynthesis via the genetically engineered microorganism Synechococcus elongatus PCC7942 designed by Dr. James Liao. Higher alcohols, especially those constructed of three to eight carbon atoms, have much utility within the dominion of chemical feedstocks and transportation fuels. They out advantage ethanol in a myriad of ways, not only through housing higher energy potential but through being more environmentally friendly via reducing net emissions. To give this claim perspective, if 60 billion gallons of higher alcohols were utilized each year as fuel substitutes (replacing 25% of gasoline) and

chemical feedstocks, Dr. Laio's technology could eliminate approximately 500 million tons of carbon dioxide emissions, which equates to approximately 8.3% of the total U.S. carbon dioxide contribution (Liao, 2010). As discussed earlier, the implications of this have much more influence on the environment beyond air quality including water quality condition, food supply, and overall health ranging from humans to the entire planet.

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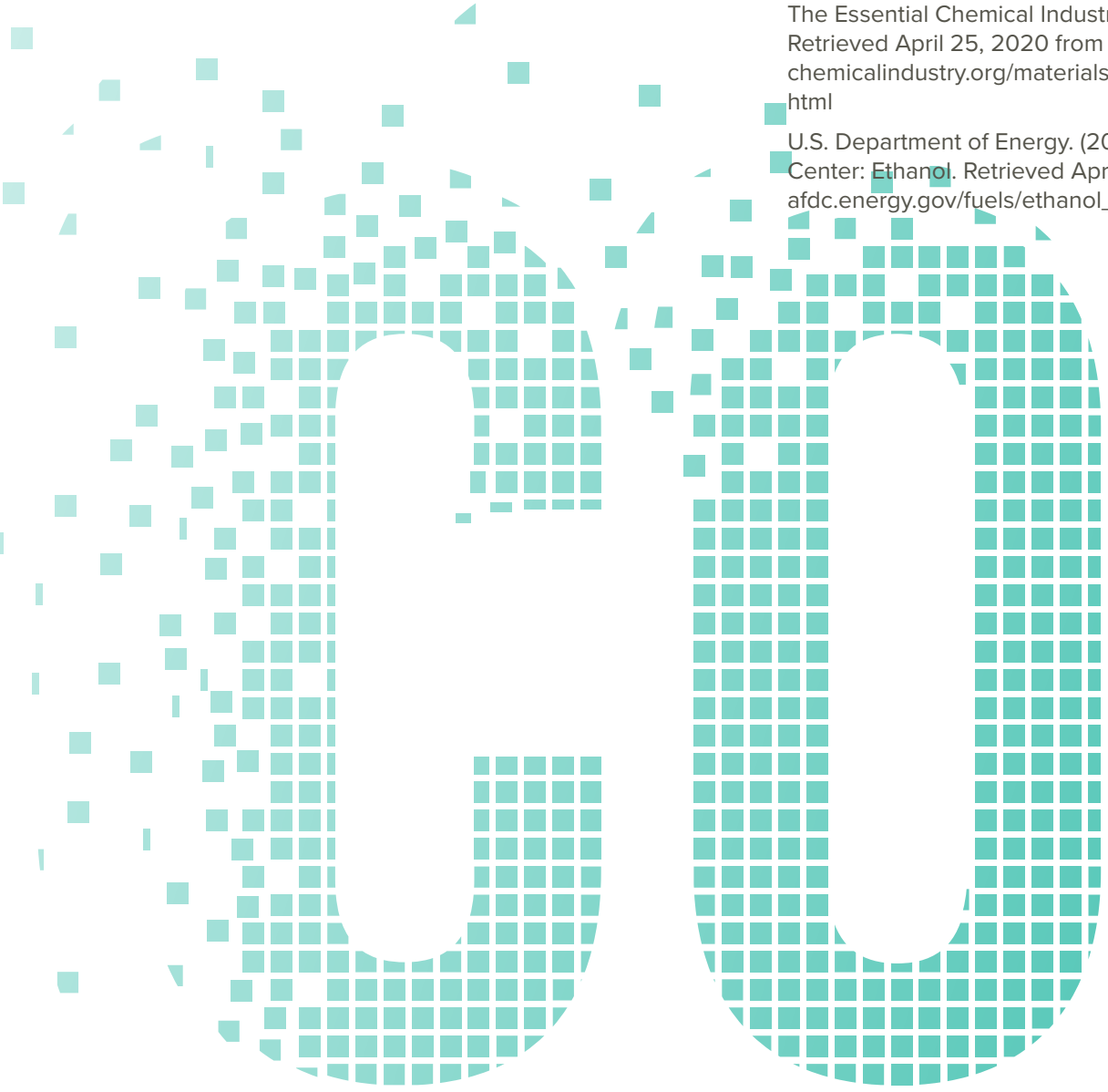

EFFECTS OF TYPE 2 DIABETES ON AGING

BY RASHIL ABUHATOUM

Consumption of carbohydrates, lipids, and proteins defines an individual's caloric intake. As the organism ingests different sources of food, a metabolic breakdown of the consumption is necessary for producing energy in the organism's body to perform work crucial to survival. The glucose molecules released by the breakdown of food result in elevated blood sugar levels, secreting insulin to chemically transport the glucose molecules from the bloodstream into the liver. The overproduction of insulin secretion can result in the cells becoming insulin resistant and glucose molecules cannot enter the cell in order to produce energy. Insulin resistance negatively affects mitochondrial aging as the concentration of ATP is decreased, highly increasing the risk to develop Type 2 diabetes mellitus. Type 2 diabetes mellitus, a chronic disease distinguished by hyperglycemia, can increase mitochondrial aging by inhibiting glycolysis due to insulin resistance, resulting in an elevation of blood glucose levels in the bloodstream.

As an individual consumes food, the body undergoes a series of intermediate steps in glycolysis to break down carbohydrates and lipids into glucose molecules. After a meal rich in carbohydrates, GLUT2, a glucose transporter, allows the movement of glucose molecules from the capillaries into the cytosol of the liver. The presence of glucose in the cytosol then progresses through metabolic reactions to break down glucose into energy via glycolysis, the tricarboxylic acid cycle, and oxidative phosphorylation pathways. Insulin, an endocrine peptide hormone, regulates the enhancement of glycolysis. This hormone secures the attachment to plasma-membrane signals in preparation for assimilating an anabolic reaction to nutrient accessibility. Insulin contributes to the progression of glycolysis by activating phosphofructokinase-2 (PFK2), an enzyme used to form fructose 2,6-bisphosphate by the phosphorylation of fructose 6-phosphate. The activation of PFK2 results in an increase of fructose 2,6-bisphosphate concentration, stimulating glycolysis. As individuals continue to eat nutrients, the hormonal levels of insulin continue to activate glycolysis, lowering the glucose levels in the blood. "When higher circulating insulin levels are necessary to achieve the integrated glucose-lowering response, a subject is considered insulin resistant." The excessive consumption of food requires an increase in insulin to regulate and metabolize food intake. However, as insulin cannot keep up with the individual's caloric intake, the body develops a resistance to it, and the ability to metabolize food regularly decreases.

Insulin resistance damages the mitochondria and induces aging as the cells of the mitochondria become weak due to the lack of absorption of glucose molecules. To demonstrate that aging is associated with the inability of the mitochondria to convert lipids to glucose metabolism, researchers assessed mitochondrial aging of glucose and fat. This study displayed that the accumulation of lipid consumption is associated with the reduction of insulin signaling, lowering the body mass of the elderly. The progression of age results in a decline of insulin sensitivity due to the body's decreasing ability to break down glucose molecules into the cell. The result of insulin resistance as individuals age lowers the number of glucose molecules that can enter the cells. The decreased breakdown of glucose molecules slows metabolism in elderly individuals, affecting body weight. Studies of insulin secretion in relation to age have been tested on various individuals. From these

studies, researchers concluded that the age of an individual impacts insulin secretion levels. This experiment was further tested on rodents. The older rodents developed a decrease in "glucose-stimulated insulin secretion" (GSIS), leading to hyperglycemia. In relation to humans, studies concluded "a decrease in insulin pulse amplitudes, and decreased response to glucose oscillations." This directly explains the linear relationship of insulin concentrations as individuals begin to age. The intake of food expands as individuals age, resulting in a greater necessity of insulin to break down glucose molecules. An abundant enhancement of glycolysis can result in the deregulation of breakdown and diabetes.

Insulin resistance is a contributor to an increase in body weight (obesity) and the development of Type 2 diabetes mellitus. As an individual continues to age, metabolic pathways require more energy to break down carbohydrates and lipids consumed into valuable fuel for the body. Due to the elevated levels of insulin, the cells are unable to ingest glucose molecules. As glycolysis enables the breakdown of those molecules, insulin resistance results in the cells being glucose deprived, and glycolysis cannot perform regularly. TPP-thiazole is a "mitochondrion-targeting group that facilitates the compound to concentrate in mitochondrion through the membrane potential of the mitochondrion developed during aerobic respiration." Studies have used this drug to experiment with the effects of mitochondrial activity concerning differences in age amongst mice. The administration of TPP-thiazole in different aged mice demonstrated the repercussions of ATP production. The results show a "45 to 47% decrease in ATP levels in the 2- and 6-month-old mice groups, confirming that this inhibitory intervention tampers ATP production." The production of ATP progresses through several steps of oxidative phosphorylation, passing electrons through complexes I, II, III, and IV and contributing to the production of reactive oxidative stress (ROS). Studies demonstrated the relationship between lipid and carbohydrate accumulation due to mitochondrial dysfunction. Results emphasized the increase of ROS produced as the consumption of food increases, damaging the mitochondria. The effect of consumption

depletes the function of the mitochondria as age progresses. While ROS are produced in relation to ATP, the physiological activation of ROS occurs at low levels of glucose signaling pathways. Upon the production of ROS, activation of the regulatory enzyme, casein kinase 2 (CK-2), activates GLUT2. This glucose transporter allows the movement of glucose molecules from the capillaries to the cytosol of the liver. The increase of ROS, therefore, results in enhanced activation of GLUT2, producing a higher concentration of glucose in the liver. This increase in glucose results in higher insulin productivity, eventually leading to insulin resistance. Insulin sensitivity then results in a buildup of glucose molecules in the bloodstream, inhibiting the liver cells to produce energy. The reduction of ATP concentration in the liver cells causes the mitochondria to take longer to break down the glucose molecules that are consumed. This decrease in ATP further impacts an individual in which the use of energy to complete tasks becomes more challenging. A lack of physical activity in individuals results in a decrease in metabolic rate, increasing the risk of weight gain.

Through the progression of age, individuals begin to enrich their diet, causing an increase in caloric intake. Although an increase in calories is correlated to metabolic energy, an excessive amount of food intake can negatively affect metabolism. The increase in calories over time results in an overabundance of insulin production in order to actively break down glucose, leading to insulin resistance. The effect of insulin resistance causes a buildup of glucose molecules in the bloodstream, increasing the risks of obesity and Type 2 diabetes mellitus. These complications of insulin resistance decrease the ATP production of mitochondrial metabolism, which results in the reduction of energy the body can use. However, by engaging in physical activity, the body has the ability to lose weight and improve insulin resistance. Aging is greatly increased and can affect the life expectancy of individuals as they continue to partake in high caloric consumption and abstain from physical activity. Although Type 2 diabetes mellitus results in numerous health conditions, this disease is not the only factor involved in the decrease of life expectancy. However, by watching glucose intake and participating in physical activity, the risk of developing health conditions decreases and can develop a positive effect on aging.

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ASYMPTOMATIC BUT STILL POSITIVE?

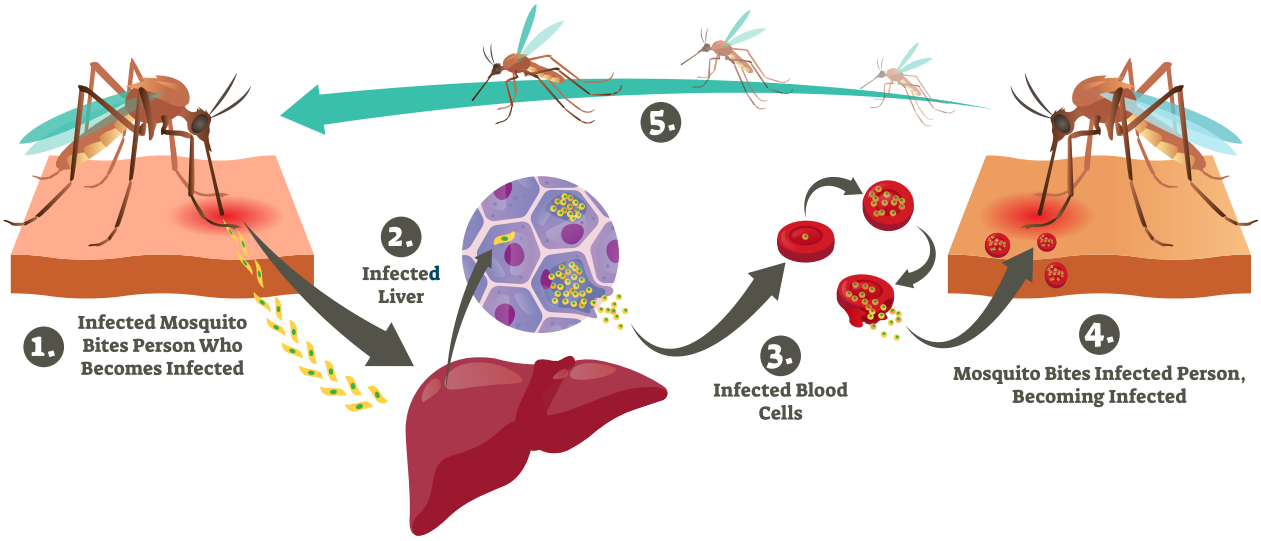
BY: THOMAS STIRRAT

#DON'TFORGETMALARIA

Thanks to CRISPR, scientists are finding better ways to identify asymptomatic malaria carriers. Despite the best efforts of organizations such as the Red Cross, Médecins Sans Frontières, and Oxfam, certain regions of Africa are rife with a disease that causes sickness and death on an unfathomable scale. This insidious monster is not Covid-19, but rather malaria. It begins with a modest fever and general malaise which rapidly evolves into shivering, chills, and profuse sweating.

Until this year, science had malaria on the run with a declining death toll over the last few decades, reaching its nadir in 2018. However, as coronavirus cases have spiked around the world, medical stockpiles have been rapidly depleted allowing for this perennial disease to launch its return. Moreover, drugs such as chloroquine have been inaccurately touted as the coronavirus cure, thus leading countries to hoard this vital malarial remedy. This in turn strips away access from those who truly need it, and contributes to drug resistance through its overuse. These shortages have forced some to even ration their prescriptions, endangering additional lives. The World Health Organization's malarial program leader, Dr. Pedro L. Alonso, remarks that "Covid-19 risks derailing all our work and taking us back to where we were 20 years ago." Lockdowns across Africa and Asia have made it nigh impossible for patients who must travel long distances to receive diagnoses and drug access.

What's more, fear of the coronavirus and inundated facilities have led patients to shy away from even trying to come in. This is further complicated by prohibitions on sea and air travel that restrict the supply of medications imported to hard-hit locales. In the thick of malaria season with limited preventative equipment (bed-nets and insecticides), public health experts are warning that if things don't begin to change, the future will look awfully grim for these nations. Global Fund estimates suggest at least $28.5 billion will be required to reverse some of the ongoing damage, a figure unlikely to be attained anytime soon.



This ruinous cascade can be traced back to an inability to properly diagnose malaria in the first place. Even just a brief delay can prove to be fatal for these patients as deadly fevers routinely spike within the first 48 hours. Despite such an immense demand, diagnostic test manufacturers have shifted their focus to the much more lucrative Covid-19 kits, thus inadvertently leaving malaria— a disease often associated with poverty— behind to fend for itself. Nonetheless, in order to eradicate this parasite, all cases in defined endemic areas need to be readily detectable by field operations at an affordable cost.

The linchpin undergirding this goal is therefore the development of a sensitive, quick, species-specific diagnostic tool that can be applicable in low-resource settings. The current methods of detection are correspondingly less precise because the clinics and hospitals in countries most impacted by malaria lack the same technological infrastructure as here in the U.S. The four major malaria-causing species are Plasmodium malariae, P. falciparum, P. vivax, and P. ovale which are currently identified by microscopic analysis of blood smears or with rapid diagnostic tests (RDTs) for antigen proteins.

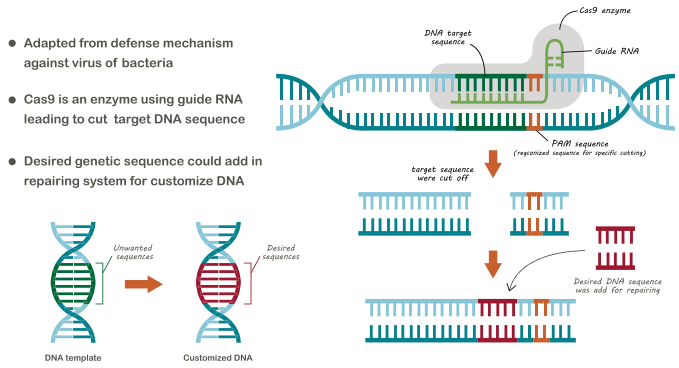
Microscopic analysis has been the gold standard, but it requires a trained expert and can be time-consuming. RDTs, which in theory sound promising, come with their own challenges. One issue has been a recent surge of false-negatives due to a gene deletion of a common RDT target in these malaria-causing species. Additionally, RDTs are unable to distinguish between each species, a problem when P. malariae and P. falciparum require different treatments than those of P. vivax and P. ovale. Neither microscopic analysis nor RDTs are able to detect the pathogen at subclinical levels.

Fortunately, a team of brilliant innovators out of the Broad Institute, a joint genomics research center affiliated with Harvard and MIT, has taken on the challenge. Their solution is a novel, malaria-based assay termed SHERLOCK (short for Specific High-sensitivity Enzymatic Reporter unLOCKing). Scientists typically refrain from using the word miracle, but SHERLOCK is an application that is truly amazing. This cutting-edge tool is said to be the pinnacle of diagnostics, with rapid and exact results at an inexpensive price. In a streamlined version, paper strips that recognize key genetic markers display results visible to the naked eye, technology akin to store-bought pregnancy tests. Once the paper strip is exposed to a processed sample, a line slowly emerges and indicates whether the patient is positive for the disease or not. This incredible process can be seen in the animation below.

At its core, SHERLOCK harnesses the extraordinary power of a system known as CRISPR-Cas9 (CRISPR is short for Clustered Regularly Interspaced Short Palindromic Repeats). Here's how it works: the repeats, small portions of viral DNA, are placed frequently across the bacterial genome. Bacteria use these in the same way a cop uses a mugshot to identify criminals. Cas9 is an enzyme that acts as a hand, guiding the

scissors the bacteria use to cut the invading DNA, in turn fighting off the virus. This, however, only works if they have that mugshot in their database. The profound discovery of CRISPR was recently recognized with a Nobel Prize awarded to its pioneers. The system is finding myriad uses across research labs as it can be programmed to target specific DNA codes within an organism. The repurposing of this tool has resulted in many experiments previously thought to be impossible.

While CRISPR is typically used as a means of gene editing, SHERLOCK applies it in a



unique fashion to diagnostics. As opposed to the typical Cas9 model, this platform takes advantage of the Cas12a variant of the enzyme, a more responsive and aggressive version. Once Cas12a finds the desired sequence, it cuts all nearby DNA and RNA indiscriminately, whereas Cas9 usually only slices at a single point. The SHERLOCK team, however, uses this mayhem to their advantage as they carefully add synthetic RNA strands that release a glowing signal when cut. This signal can then be detected on a readout, such as paper strips. This allows for a clear and efficient way of determining the presence of malaria, as well as delineating between each of the four species.

Simply put, SHERLOCK has the wherewithal to revolutionize the way in which low-income areas approach the problem of detecting this menacing disease. The SHERLOCK application is particularly striking as it requires minimal instrumentation or prior training, and can be employed seamlessly in the rural field setting where reliable electrical power and refrigeration are not always available. The SHERLOCK strategy needs only a blood draw, followed by a 10-minute specimen preparation and a 60-minute protocol.

This method demonstrates accuracy that surpasses the WHO's recommendation of two parasites per microliter of the sample, meaning that SHERLOCK is able to detect all asymptomatic cases with ease. Impressively, it has been determined that the level of parasitemia found by SHERLOCK is equivalent to a technician having to view over 100,000 RBCs. Other simulations reinforce these same findings, showing that RDTs and light microscopy are only half as accurate as SHERLOCK. As it stands, SHERLOCK appears to be the answer to countless prayers and is perhaps a silver lining amidst this suffering. While systems have proven unwilling to change in the past, there is nothing more powerful than a major crisis challenging us to change the way we look at things.

> "[This field-ready SHERLOCK diagnostic's] highly streamlined design could provide a viable solution to the present diagnostic bottleneck on the path to eliminate malaria, and more fenerally enabling malaria surveillance in low-resource settings" - James Collins

Despite the huge difficulties of 2020 due to the coronavirus, this year has also brought with it the birth of SHERLOCK: an unconventional technology for diagnosing diseases. SHERLOCK initially started as a pilot program for malaria, but through continuous refinement and future iterations, it is poised to take healthcare by storm with implementations elsewhere, namely dengue fever, zika virus, and even cancer. The ingenuity and creative thinking of these bioengineers cannot be expressed enough as SHERLOCK opens the door to untold possibilities. Through their hard work, perhaps the future is not as bleak as some may have feared. The hope is that the use of SHERLOCK will begin to gain traction around the world and ultimately become commonplace, especially in regions struggling to combat malaria.

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