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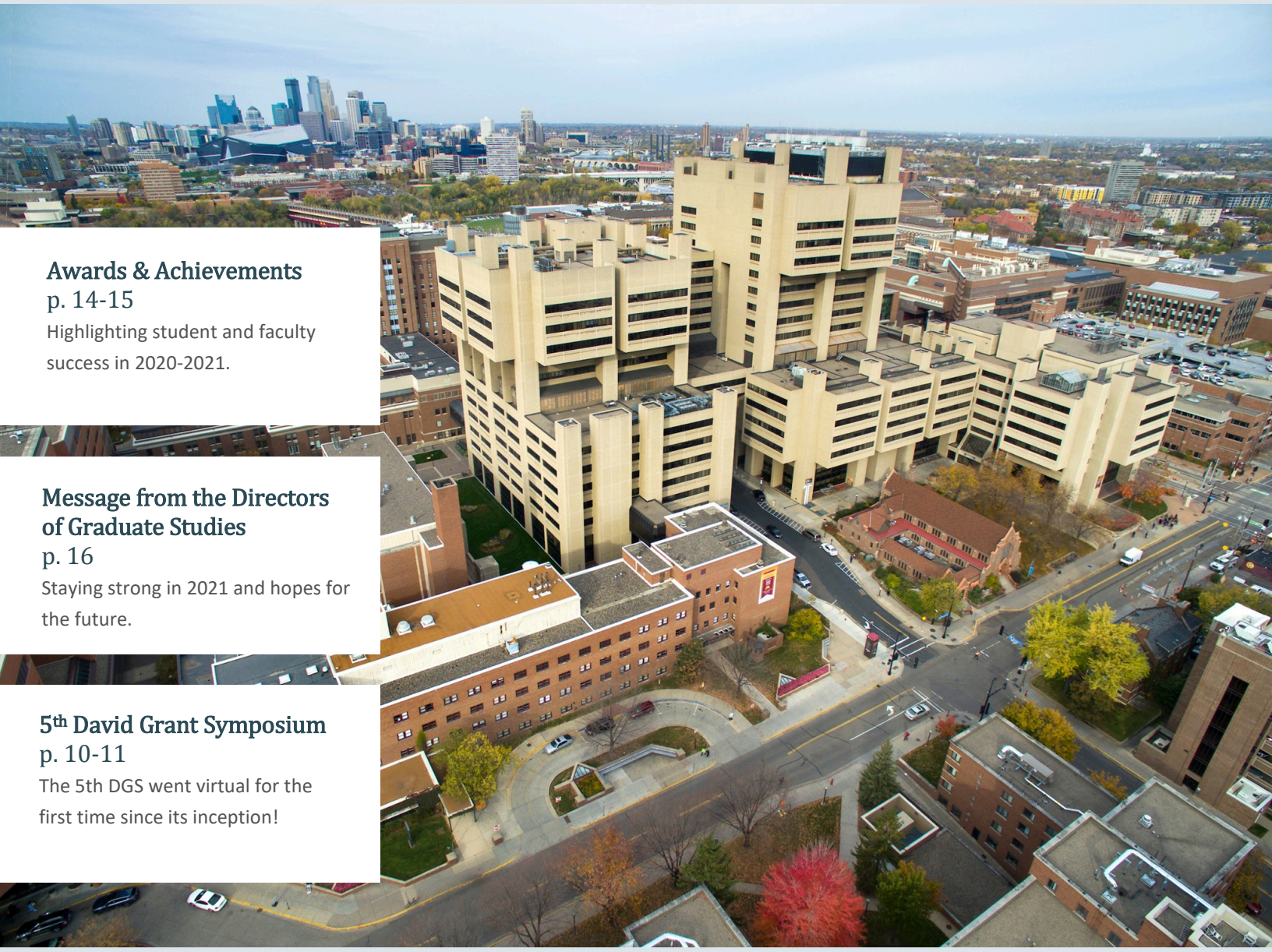
MINNECEUTICS

Indispensable News.

University of Minnesota Department of Pharmaceutics



Awards & Achievements
p. 14-15
Highlighting student and faculty success in 2020-2021.

Message from the Directors of Graduate Studies
p. 16
Staying strong in 2021 and hopes for the future.

5th David Grant Symposium
p. 10-11
The 5th DGS went virtual for the first time since its inception!

2021 Issue

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A Message to Our Friends

Dear friends,

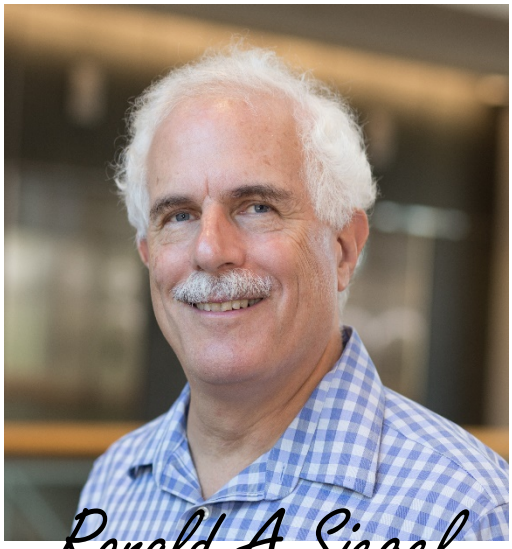
Life is like a puzzle: full of pieces that, at first glance, seem unending and unrelated. However, if we take our time, the pieces start to fit together and slowly reveal the bigger picture. Although it is disappointing that 2021 did not herald a full return to normal, we are making progress piece by piece. Let us celebrate the pieces that have come together.

A large piece of the puzzle was how to return to campus in a safe manner. This June, the University of Minnesota launched the Work with Flexibility initiative, allowing employees to negotiate their return to work based on individual needs. Following suit, our Pharmaceutics faculty continue to offer hybrid online/in-person courses, including our seminar series, to provide flexibility to our students as they care for themselves and others.

Our department has also reopened our shared spaces in ways that balance community with safety. We have created smart codes that department members can scan to schedule a room for private use, added signage to doors that indicate occupied/vacant status, and provided HEPA air filters in each space. Such measures are designed to allow our members to interact at their comfort level as we make our way back to normal operations.

Another piece of the puzzle was how to better support our students, not only in these extraordinary times, but also in general as they adapt to campus and graduate program life. Our graduate students have developed a buddy program that pairs newly admitted students with senior students in our department. The program helps new students with the day-to-day struggles of commuting, dining, housing, etc., and builds community among students by encouraging them to engage in social events. Overall, there was great enthusiasm for this program department-wide, and I am proud of the 20 students currently participating in it. If you're interested in learning more about the buddy program, please email pceut-buddy@umn.edu. (Click here to see pictures of its launch event on page 19).

Lastly, we puzzled over how to best reach all of you. For now, the answer is still to 'go virtual'. However, that does not mean we will compromise quality. For example, the 5th David Grant Symposium, held virtually this past June for the first time since its inception, was able to include an even greater number of participants from around the world by removing the barrier of travel. Similarly, our virtual alumni event held early last December was well attended and received. We thank all of you who participated in these events and recognize that your presence is a powerful factor in our success. A second virtual alumni event is planned for this coming December (Invitation included on page 18).



Ronald A. Siegel
Interim Department Head

In closing, I welcome your feedback on any departmental activity and look forward to the time when we can safely meet again at professional meetings. Until then, please take care and stay safe.

Meet Our Faculty

William F. Elmquist, PharmD, PhD
Distinguished Professor, Pharmaceutics
Director, Brain Barriers Research Center

Carolyn A. Fairbanks, PhD
Professor, Pharmaceutics
Associate Dean for Research and Graduate Education, College of Pharmacy

Karunya K. Kandimalla, PhD
Associate Professor and Associate Director of Graduate Studies, Pharmaceutics

Hongbo Pang, PhD
Assistant Professor, Pharmaceutics

Henning Schroeder, PhD
Director of International Programs, College of Pharmacy
Professor, Pharmaceutics

Ronald A. Siegel, ScD
Professor and Interim Department Head, Pharmaceutics

Changquan Calvin Sun, PhD
Professor, Director of Graduate Studies, and Associate Department Head, Pharmaceutics

Raj Suryanarayanan, PhD
Professor and Peters Endowed Chair, Pharmaceutics

Timothy S. Wiedmann, PhD
Professor, Pharmaceutics

Adjunct Faculty

Aktham Aburub, PhD, Eli Lilly & Co.

Walid M. Awni, PhD, Intellia Therapeutics, Inc.

Richard C. Brundage, PharmD, PhD, Experimental & Clinical Pharmacology, U of M

Lester R. Drewes, PhD, Biochemistry & Molecular Biology, U of M Duluth

Virginia Ghafoor, PharmD, Fairview Pharmacy Services

Purna Kashyap, MBBS, Mayo Clinic

Susan Krueger, PhD, NIST Center for Neutron Research

David A. Largaespada, PhD, Genetics, Cell Biology & Development, U of M

Z. Jane Li, PhD, Pharmaron

Mukesh Pandey, PhD, MRSC, Mayo Clinic

Jayanth Panyam, PhD, Temple University

Theresa M. Reineke, PhD, MS, Chemistry, U of M

Jann N. Sarkaria, MD, Mayo Clinic

Ronald J. Sawchuk, PhD, Professor Emeritus

Evgenyi Y. Shalaev, PhD, Allergan

Rachael Sirianni, PhD, MS, MSE, University of Texas Health Science Center at Houston

Robert Thorne, PhD, Denali Therapeutics

Chun Wang, PhD, Biomedical Engineering, U of M

Zheng Yang, PhD, Bristol Myers Squibb

Joseph A. Zasadzinski, PhD, Chemical Engineering & Materials Science, U of M

Cheryl L. Zimmerman, RPh, PhD, Professor Emeritus

Degrees Earned in 2020-2021

Congratulations to all our graduates

Kweku Konadu Amponsah-Efah, PhD
Advisor: Professor Raj Suryanarayanan
Thesis: *Effects of additives on the molecular-level behavior of disordered pharmaceuticals*

Fangyi Dong, MS
Advisors: Professors Jayanth Panyam and Timothy Wiedmann
Thesis: *Manganese doped silica nanoparticles for acidic pH responsive TLR7 agonist delivery*

Ishaan Duggal, MS
Advisors: Professor Ronald Siegel
Thesis: *Temperature and water responsive shape memory polymers for soft tissue expansion*

Yiwang Guo, PhD
Advisors: Professor Calvin Sun
Thesis: *Tablet dissolution deterioration by sodium lauryl sulfate - mechanism and mitigation strategies*

Krutika Harish Jain, PhD
Advisor: Professor Ronald Siegel
Thesis: *Artificial gut simulator for simultaneous evaluation of drug dissolution and absorption*

Navpreet Kaur, PhD
Advisor: Professor Raj Suryanarayanan
Thesis: *Understanding the stability of salts and cocrystals in a drug product environment*

Chenxu Li, MS
Advisor: Professors Karunya Kandimalla and Timothy Wiedmann
Thesis: *Effect of anti-amyloid β antibody on Aβ trafficking at the blood-brain barrier*

Manan Chandraj Shah, MS
Advisor: Professor Jayanth Panyam
Thesis: *Combination of STING and TLR 7/8 agonists as vaccine adjuvants for cancer immunotherapy*

Sichen Song, MS
Advisor: Professor Ronald Siegel
Thesis: *Development of amorphous solid dispersion tablet of sorafenib with improved oral bioavailability*

Commencement

Attended dept. celebration and college commencement:

Yiwang Guo, PhD
Chenxu Li, MS
Zijian Wang, MS

Attended college commencement:

Manan Shah, MS
Vrishali Salian, MS

Congratulations to the class of 2021

Welcome New Students!

Arushi Agarwal
MS program
Advisor: Sun
BPharm, Nirma University

Muskan Badola
MS program
Advisor: Kandimalla
BPharm, Nirma University

Vedant Bhagali
MS program
Advisor: Sun
BPharm, Savitribai Phule Pune University

Kiki Gai
MS program
Advisor: Sury
BS in Chemistry,
BS in Mathematics,
Univ. of Minnesota-Twin Cities

Vineetha Guttha
MS program
Advisor: Kandimalla
BPharm, Chalapathi Institute of Technology and Sciences

Doug Nelson
PhD program
Advisor: Kandimalla
BS in Mathematics,
BS in Chemistry,
Univ. of Minnesota-Twin Cities

Vikram Joshi
PhD program
Advisor: Sun
MS in Pharmaceutics, National Institute of Pharmaceutical Education & Research,
BPharm, Savitribai Phule Pune University

Vaishnavi Veerareddy
MS program
Advisor: Kandimalla
MTech in Pharmaceutical Tech - Process Chemistry, Ntl Institute of Pharmaceutical Education and Research
Bachelor of Pharmacy, Anurag Group of Institutions

Nianwu Wang
MS program
Advisor: Pang
BS in Biomedical Science, Southern University of Science and Technology

Zijian Wang
PhD program
Advisor: Sun
BS in Pharmaceutics, Shenyang Pharmaceutical University

Tianyi Xiang
MS program
Advisor: Sun
BS in Pharmacy, Shenyang Pharmaceutical University

Jiaqi Zhao
MS program
Advisor: Pang
BE in Pharmaceutical Engineering, Guangzhou University of Chinese Medicine

Welcome to the World!

2020-2021 Minneceutics Minis

Kyra
Born in April 2021
Proud parents:
Pinal & Brijesh

Ayush
Born in May 2021
Proud parents:
Anasuya & Ram

Veer
Born in June 2021
Proud parents:
Khushboo & Amit
Pictured with his older sister, Mishka.

Stella
Born in July 2021
Proud parents:
Yan & Hongbo
Pictured with her older sister, Lingzi (Lindsey).

pharmacy.umn.edu/departments/pharmaceutics

Congratulations!

2021 Minneceutics Marriages

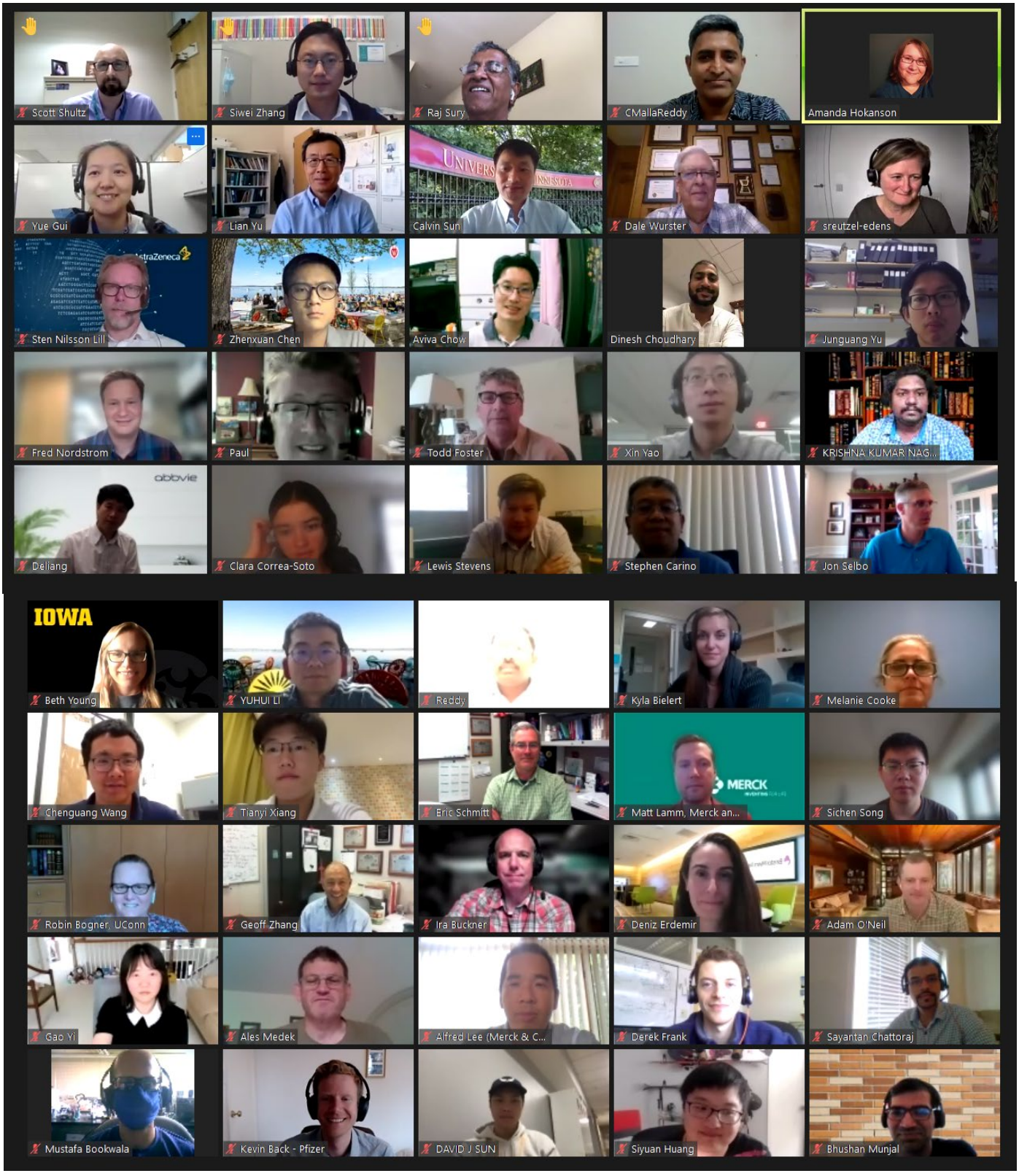
Jessica Griffith & Ray Theiler
Married in April 2021

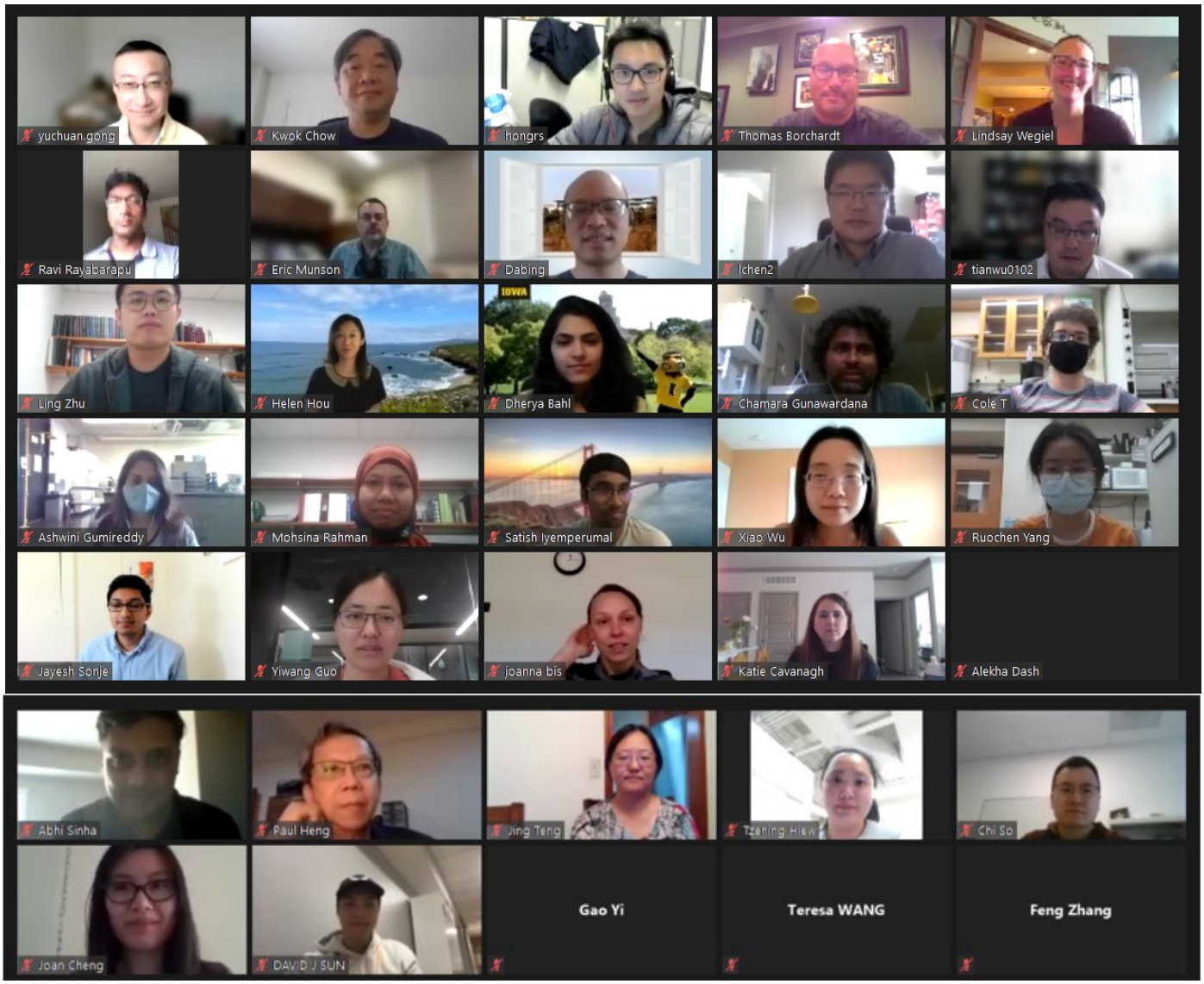
Anqi Lu & Junhuang Jiang
Married in May 2021

5th David Grant Symposium

A special thank you to the nearly 180 participants worldwide who attended the symposium this year!

We were thrilled to see so many people passionate about solid-state pharmaceuticals. Although we would've liked to have seen you on campus, we are glad you could join us and look forward to seeing you in 2023!





Attendees not shown:

- Gao Yi
- Teresa Wang
- Feng Zhang
- Peter Wildong
- Su Yuan
- Siddharth Tripathi
- Navpreet Kaur
- Ken Morris
- Natalia
- Ruosong Dong
- Yiqing Lin
- Amy Neusaenger
- Aaron Goodwin
- Tongzhou Liu
- Da Hye Yang
- Van Tu Duong
- Martin Coffey
- Thuy Nguyen
- Greg Nottingham
- Zaid Assaf
- Limin Shi
- Zijian Wang
- Edward Yost
- Frederick Osei-Yeboha
- Jennifer Lewis
- Bianfei Xuan
- Devalina Law
- Ophelia Zhang
- Deanna Mudie
- Hongbo Chen
- Tu Van Duong
- Gislaine Kuminek

2021-2022 Fellowships & Grants

Awardee: Jayesh Sonje
Advisor: Dr. Raj Suryanarayanan

David J.W. Grant and Marilyn J. Grant Fellowship in Physical Pharmacy (2021-2022)

This fellowship is awarded to students whose research is focused in Physical Pharmacy.

U of M Council of Graduate Students (COGS) Career Development Grant

This grant is intended to help develop graduate student careers by making trainings and workshops more affordable. It was awarded to Jayesh for attending the X-ray diffraction clinic hosted by the International Centre for Diffraction Data (ICDD) in May 2021.

Awardee: Surabhi Talele
Advisor: Dr. William Elmquist

Ronald Sawchuk Fellowship

This award is given to graduate students whose research is focused in Pharmacokinetics.

Doctoral Dissertation Fellowship

The DDF gives the University's most accomplished Ph.D. candidates an opportunity to devote full-time effort to an outstanding research project by providing time to finalize and write a dissertation during the fellowship year. Awarded for "Optimizing chemo- and radio-sensitizing drug regimens that inhibit DNA damage response (DDR) mechanisms for brain tumor therapy".

Awardee: Joel Updyke
Advisor: Dr. Ronald Siegel

Edward G. Rippie Fellowship

This fellowship is awarded to students with a consistent and outstanding academic record in Pharmaceutics.

2020-2021 Fellowships & Grants

Awardee: Zengtao Wang

Advisor: Dr. Karunya Kandimalla

Edward G. Rippie Fellowship

This fellowship is awarded to students with a consistent and outstanding academic record in Pharmaceutics.

Awardee: Wenjuan Zhang

Advisor: Dr. William Elmquist

Ronald Sawchuk Fellowship

This award is given to graduate students whose research is focused in Pharmacokinetics.

Awardee: Andrew Zhou

Advisor: Dr. Karunya Kandimalla

Doctoral Dissertation Fellowship

The DDF gives the University's most accomplished Ph.D. candidates an opportunity to devote full-time effort to an outstanding research project by providing time to finalize and write a dissertation during the fellowship year. Awarded for "Insulin resistance promotes blood-brain barrier dysfunction during aging, type-II diabetes, and Alzheimer's disease".

Awards & Achievements

Highlighting Success in 2020-2021

Rahul Lalge

Robert L. Synder Student Award

Awarded at the Denver X-ray Conference in 2021.

IPEC Graduate Student Award

Awarded at AAPS PharmSci 360 Conference held in Philadelphia, PA. Granted by the International Pharmaceutical Excipient Council of the Americas Foundation (IPEC) for 2021. The scholarships focus on recent significant contributions to formulation science and technology through innovative research with excipients.

Jayesh Sonje

IPEC Graduate Student Award

Granted by the International Pharmaceutical Excipient Council of the Americas Foundation (IPEC) for 2021. The scholarships focus on recent significant contributions to formulation science and technology through innovative research with excipients.

Surabhi Talele

JPET Award:
Highlighted Trainee Author

This award was granted by the Journal of Pharmacology and Experimental Therapeutics for the December 2021 issue to Surabhi for her article titled, *"Brain Distribution of Berzosertib: An ATR Inhibitor for the Treatment of Glioblastoma*".

Vrishali Salian

College of Pharmacy 2021 3MT Competition: Judges Winner

This competition challenges research students to communicate the significance of their thesis projects to a general audience in just three minutes with the aid of a single static slide. This award includes a $1000 travel grant.

University of Minnesota-wide Three Minute Thesis (3MT) Winner

Vrishali will go on to represent the University of Minnesota at the Midwestern Association of Graduate Schools (MAGS) 3-Minute Thesis competition. In addition, she will be invited to present her research at an upcoming Board of Regents meeting. Vrishali's presentation is titled, "*Identifying early signs of Alzheimer's disease: An attempt to color lives*."

2020-2021 Outstanding TA Award:

This award recognizes outstanding performance of teaching assistants in the College of Pharmacy's PharmD program.

Best Poster Award: Runner Up

At the 12th annual Pharmaceutical Science Research Symposium organized by University of Pittsburgh's AAPS student chapter.

Awards & Achievements
Highlighting Success in 2020-2021

Dr. William Elmquist
2020-2021 Distinguished Teaching Award

This award was established in 1999 to "recognize [outstanding] contributions to graduate and professional education. Recipients are chosen for excellence in instruction; involvement of students in research, scholarship, and professional development; development of instructional programs; and advising and mentoring of students." Dr. Elmquist will be inducted into the Academy of Distinguished Teachers and carry the designation of Distinguished University Teaching Professor throughout his careers at the University of Minnesota. Additionally, his name will be engraved in the Scholars Walk as a Distinguished University Teaching Professor.

Dr. Carolyn Fairbanks
New R21 grant (co-investigator)

Entitled, "Characterization of a novel spinal astrocyte-neuron signaling system in chronic pain". The award is from the National Institute on Neurological Disorders and Stroke. The Principal Investigator is Prof. Alonso Guedes of the College of Veterinary Medicine.

Dr. Karunya Kandimalla
(New) Director of Graduate Studies

Dr. Kandimalla, having served as Associate Director of Graduate Studies in the Pharmaceutics Graduate Program for three years became the primary DGS on Aug 1, 2021. He's excited to lead our excellent program, continue to support our students, and help the program achieve new heights.

Dr. Changquan Calvin Sun
(New) Associate Department Head

Dr. Sun, having served for six years as the primary Director of Graduate Studies in the Pharmaceutics Graduate Program has passed the baton to Dr. Kandimalla and has taken up the mantle of Associate Department Head.

Dr. Raj Suryanarayanan
2021 Michael J. Pikal NIPTE Distinguished Scholar Award in Pharmaceutical Processing

This award, according to the National Institute for Pharmaceutical Technology and Education (NIPTE) website, is the highest recognition awarded by the organization on an annual basis. Recipients of the award demonstrate outstanding scientific achievements in pharmaceutical science and technology.

PD1 Professor of the Semester Award

This award is given to acknowledge all of the hard work faculty put into the semester to make the class thrive. Students vote on which faculty were truly an influential part of their learning.

From the Directors of Graduate Studies

Dear Friends and Colleagues,

Since the beginning of the Fall semester this year, the UMN community has come back strong from the long remote working life style in response to the COVID-19 pandemic. Laboratory activities have essentially returned to the pre-pandemic levels, with the main difference of the mandatory face covering and social distancing. In-person instruction is offered for classes, while remote participation is allowed with adequate justification. Approximately half of the department attend department seminars in person.

A total of 4 PhD students and 5 MS students graduated from our program in the past year. As you will see in the earlier sections of this newsletter, our students continue to win awards and maintain outstanding research productivity. It is clear that both the faculty and students have demonstrated tremendous resolve to make the department and the graduate program stronger, despite various challenges presented by COVID. Through our joint efforts, we continue to be one of the best in Pharmaceutics programs in the nation.

This year again, we had a large number of exceptionally strong candidates apply to our program. However, we could only accept 3 new PhD students and 9 MS students. The large number of MS admissions reflect the high level of demand for our MS program. In response to the rising living costs, our department has decided to raise the stipends of PhD students. This is expected to help our students focus on research without financial concerns and also enhance our ability to attract top candidates to our graduate program. Speaking of admissions, we have streamlined the application process to make online application more efficient. We are also producing videos to showcase our research accomplishments and to celebrate the successes of our graduate program. This will allow prospective applicants to take a closer look at the outstanding program we have. We also resumed our summer research internship program this year, which is designed to introduce our program to domestic students and engage them early in their undergraduate careers.

We also had a change of leadership of our graduate program. Prof. Kandimalla succeeded Prof. Sun as the Director of Graduate Studies in August. Having served as the Associate DGS for three years, Prof. Kandimalla is well prepared to lead our graduate program to the next heights. Prof. Sun wishes to thank Prof. Kandimalla for his willingness to take on this important responsibility. It was a great journey for Prof. Sun to serve the faculty and students in this role over the past 6 years. Our graduate program is now in Prof. Kandimalla's capable hands.

Finally, please remember that we have a standing invitation for you to play an active role in our graduate program. Given the resounding success of the virtual alumni event last year, we are holding it again this year on December 3rd. We hope to see many of you there.

Until then, stay safe and healthy.

Changquan Calvin Sun, PhD

Associate
Department Head

Karunya Kandimalla, PhD

Director of Graduate Studies

Graduate Student Organizations
Elected 2021-2022

AAPS UMN Student Chapter Officers

Chair
Sneha Rathi
Pharmaceutics

Chair-Elect
Chenxu Li
Experimental & Clinical Pharmacology

Treasurer
Vikram Chandrashekhar
Pharmaceutics

Secretary
Zengtao Wang
Pharmaceutics

Web Coordinator
Joel Updyke
Pharmaceutics

Student Outreach
Muskan Badola
Pharmaceutics

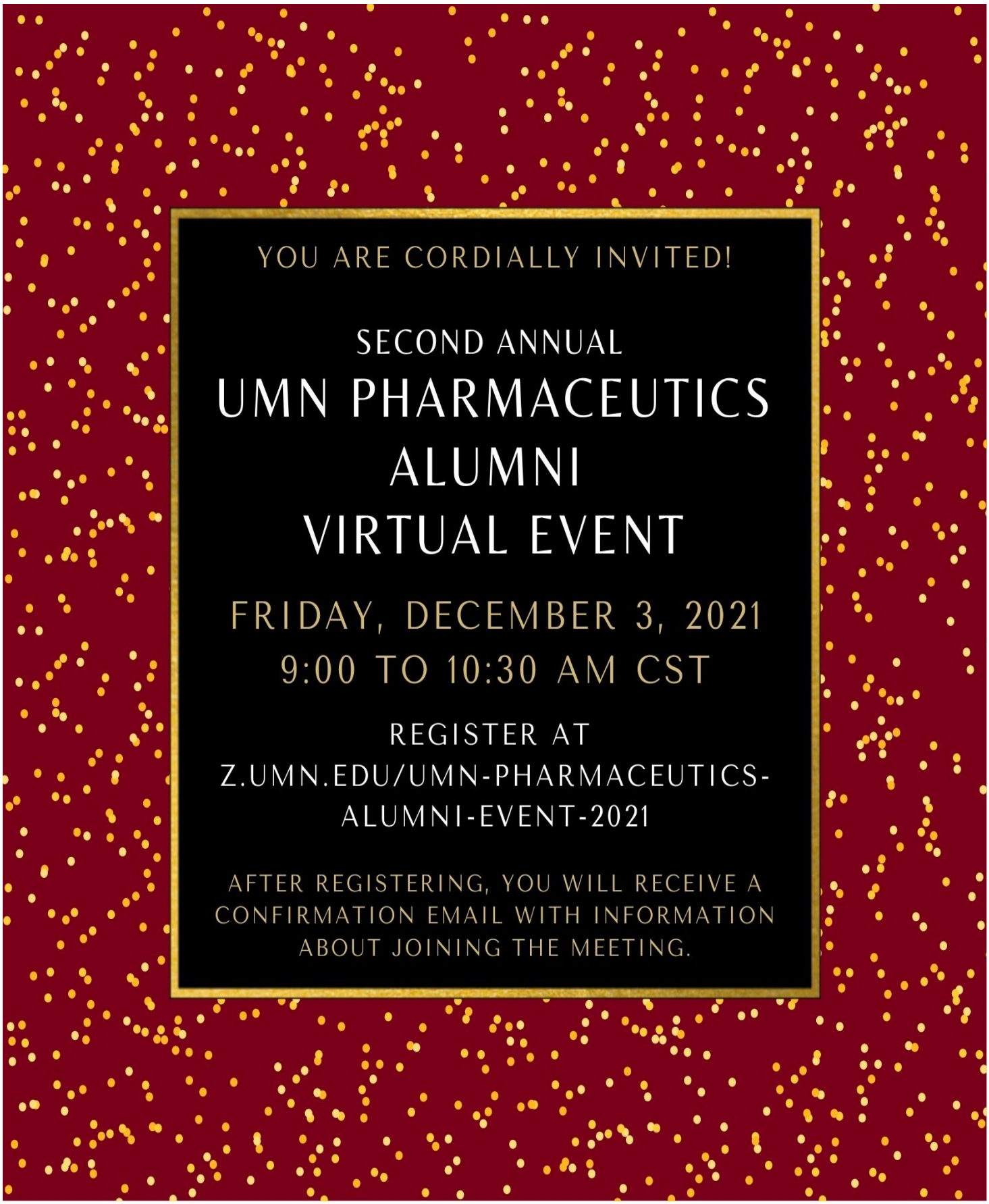
Pharmaceutics Graduate Student Representatives

Gerrit Vreeman
Pharmaceutics

Rahul Lalge
Pharmaceutics

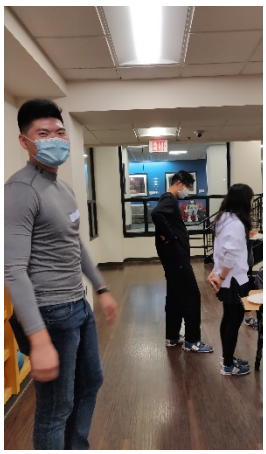
COGS & CIGS Pharmaceutics Representative

Tvisha Shah
Pharmaceutics


YOU ARE CORDIALLY INVITED!
SECOND ANNUAL
UMN PHARMACEUTICS ALUMNI VIRTUAL EVENT
FRIDAY, DECEMBER 3, 2021
9:00 TO 10:30 AM CST
REGISTER AT
Z.UMN.EDU/UMN-PHARMACEUTICS-ALUMNI-EVENT-2021
AFTER REGISTERING, YOU WILL RECEIVE A CONFIRMATION EMAIL WITH INFORMATION ABOUT JOINING THE MEETING.

Buddy Program

Student Kickoff Event



Buddy Program

Students Supporting Students

Thank you to all those who participated!

Back Row:

Zijian Wang
Zengtao Wang
Jayesh Sonje
Doug Nelson
Nianwu Wang
Kiki Gai
Ben Clements
Vedant Bhagali
Tianyi Xiang
Jibin Guan

Front Row:

Vaishnavi Veerareddy
Wenqiu Zhang
Lushan Wang
Sneha Rathi
Vikram Joshi
Vrishali Salian
Sanjana Nair
Tvisha Shah
Arushi Agarwal
Muskan Badola
Vineetha Guttha

A Blast from the Past

Recognize them?

Photo 1: Sitting, (L to R): Bill Elmquist, Mohsen Hedaya, Hani Ayad, Lillian Riyad.
Standing, (L to R): Mayette Wong, Lyn Sawchuk, Belinda Cheung, Helen Chan, Shekman Wong. Standing behind Helen is Yanfeng Wang. *(New Brighton, MN, 1990)*

Photo 2: Dick Brundage
Photo 3: Zheng Yang

Photo 4: (L to R): Keith Chan, and his faculty adviser/mentor, Professor Kenneth (Ken) W. Miller. Ken was on faculty in the Dept of Pharmaceutics from 1971 to 1982.

Photo 5: (L to R): Bimal Malhotra and Ron Sawchuk

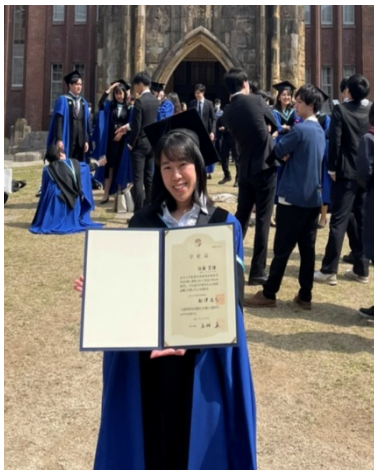
Photo 6: Sitting, (L to R): Ron Siegel, Ron Sawchuk, Tim Wiedmann.
Standing, (L to R):
Cheryl Zimmerman, Raj Sury.
(1999)

A Year in Photos

Suneel Rastogi, daughters Shreya & Saumya, and wife Preeti

Drs. Raj Suryanarayanan, Ronald Siegel, and William Elmquist at the Distinguished Teachers Annual Ceremony.

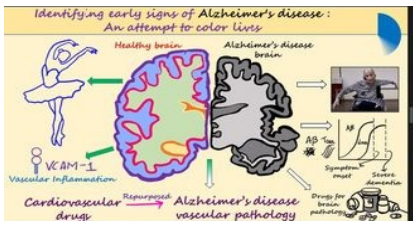
Rahul Lalge (bottom left) and some of his colleagues at GlaxoSmithKline (pictured from left to right): Rattavut T., Dimple M., Rahul L., Janine K., Zeinab K., Rahul S.



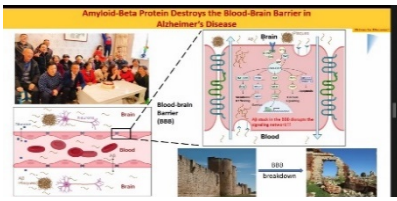
Nozomi Hanawa completed graduate school at the University of Tokyo and entered the School of Medicine at Osaka University.

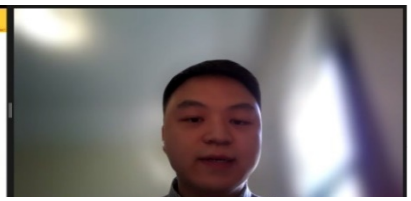
IPEC 2021 *Award Ceremony* (L) Rahul Lalge & (R) Jayesh Sonje with their advisor Dr. Raj Sury

Vrishali Salian presenting her poster for the 3-minute thesis competition. Vrishali later won the UMN-wide level of the competition.



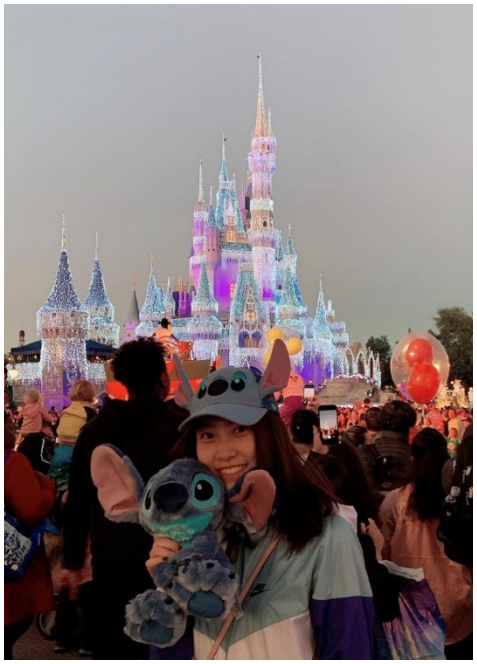
Katie James representing the Pharmaceutics program at the UMN 2021 Life Sciences Graduate School Fair.



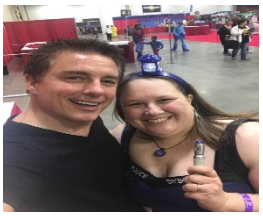
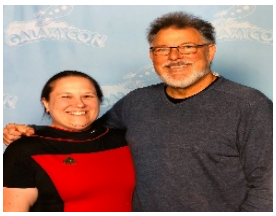


Zengtao Wang presenting his poster for the 3-minute thesis competition.

Pceuts at Play







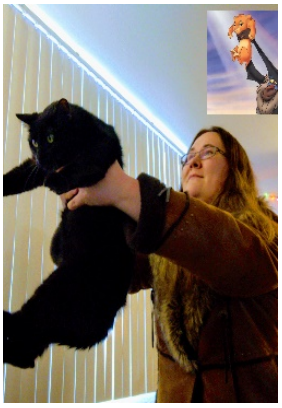
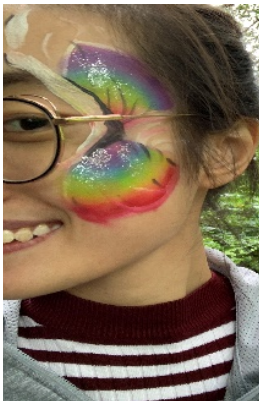
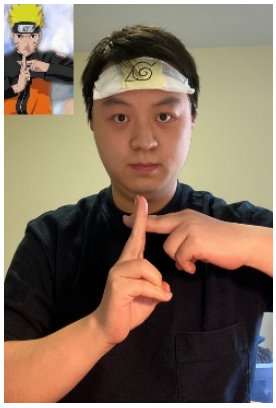








Photo 1: Kiki Gai at Disneyland. **Photo 2:** Surabhi Talele going to Hogwarts. **Photo 3**: Katie James (KJ) and actor Adam Savage. **Photo 4**: KJ and actor Christopher Eccleston. **Photo 5**: KJ actor John Barrownman. **Photo 6:** KJ and actor Jonathan Frakes. **Photo 7**: KJ and voice actor Steve Blum. **Photo 8:** KJ and voice actor John DiMaggio. **Photo 9:** A Band of "Bens". The Fairbanks lab group dressed as one of their graduate students, Ben Clements, for Halloween. **Photo 10:** Vrishali Salian and her friend dress up as Mario & Luigi for Halloween. **Photo 11:** Amanda Hokanson and Persia reenact a scene from *The Lion King* for the departmental scavenger hunt. **Photo 12:** Wenjuan Zhang doing beautiful facepaint for the scavenger hunt. **Photo 13:** Zengtao Wang creating a COVID-19 version of *Naruto* for the scavenger hunt. **Photo 15**: Makarand Jawadekar (MJ) with Greg Reid at Secret Knock. **Photo 16:** MJ with actress Claudia Wells from *Back to the Future*. **Photo 17:** MJ with actor Gary Busey from *Back to the Future*. **Photo 16:** MJ with actor Gary Busey on the movie set of 1978's "Foolin' Around". **Photo 18:** Chenxu Li wins the Pharmaceutics DIY Halloween costume competition with her spooktacular face makeup.

Milestones

Life updates from students, staff, and alumni

Shaukat Ali, a friend of the University who completed his postdoc at the UMN Hormel Institute (1989-1991) in Austin, Minnesota, was awarded with IPEC Foundation's industrial research award in 2020.

Benjamin Clements, a graduate student in Dr. Carolyn Fairbanks' lab, was selected to present his poster titled, "Agmatine-Based Prodrugs for Chronic Pain and Opioid Addiction: Pharmacokinetics and Pharmacodynamics" in the Special Poster Collection, organized by AAPS President Andrew Vick for the 2021 Annual Meeting.

Wenqi (Kiki) Gai, a graduate student in Dr. Raj Suryanarayanan's lab, originally from Inner Mongolia in China, was accepted into the MS graduate program this year. Kiki likes jogging, movies, bunnies, ballet, reading books, and has said she enjoys the lakes and snow in Minnesota.

Takehisa Hanawa, a 2005-2006 visiting professor in Dr. Ronald Siegel's lab, has been spending his days as a Professor at the Tokyo University of Science, teaching both undergraduate and graduate students. Takehisa is currently studying the development of formulations for healing wounds.
His wife, Tomoko, is also busy as a Professor at the Laboratory of Microbiology, School of Medicine, Kyorin University in Tokyo. Their son, Takanori, is now working as a writer for a newspaper company in Osaka. Their daughter, Nozomi, has completed graduate school at the University of Tokyo and entered the School of Medicine at Osaka University. She wants to be a medical doctor and pathologist.

Amanda Hokanson, Executive Office & Administrative Specialist for Pharmaceutics, entered the 2nd year of her MS in Training and Human Resource Development (TRHRD) at the Univ. of WI- Stout. Additionally, she completed the Project Management professional certificate program offered through the University of Minnesota and was selected for the second cohort of the Leading Change and Project Management Initiative. Amanda will be celebrating six years with the Pharmaceutics Department on Dec. 7, 2021. She also designed the newsletter again this year, so if you like it- let her know!

Katie M. James, Office Supervisor and Graduate Program Coordinator for Pharmaceutics, will be celebrating her 10-year work anniversary with the University of Minnesota this December. She is also on track to complete training to become a Mental Health Advocate by the end of the year.

Navpreet Kaur, a 2020 PhD graduate of Dr. Raj Suryanarayanan's lab, received 2021 The Ludo Frevel Crystallography Scholarship to pursue crystallographically-oriented research. The International Centre for Diffraction Data (ICDD) established the Crystallographic Scholarship Program in 1991. Later renamed to honor the founder of the fund, Dr. Ludo Frevel, the scholarships support the education and research of graduate students in the science of crystallography and related fields. Navpreet also received the 2021 President's Student Leadership and Service Award.

Rahul Lalge, a graduate student in Dr. Raj Suryanarayanan's lab, successfully completed a summer internship at GlaxoSmithKline in Upper Providence, PA in the Parenteral Formulation Development department from June-August 2021. He also presented an award-winning poster at the 2021 Denver X-ray Conference entitled "*Crystallization in Amorphous Pharmaceuticals: Understanding the Role of Cooling Rate during Preparation from Melt*" in August. Furthermore, Rahul presented a poster entitled, "*Crystallization in Amorphous Pharmaceuticals: Understanding the Role of Cooling Rate during Preparation from Melt*" at the 2021 AAPS/PharmSci 360 annual conference held in Philadelphia, PA.

Jinghan Li, a graduate student in Dr. Raj Suryanarayanan's lab, joined the Material and Analytical Science (MAS) department at Boehringer Ingelheim as a summer intern. The internship focused on the impact of impurities on the crystal morphology and phase transformation.

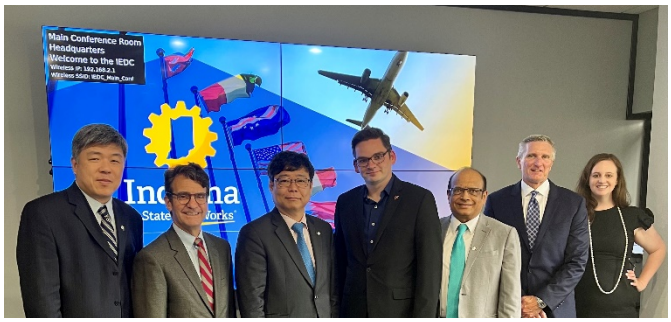
Anqi Lu, a 2020 MS graduate of Dr. Jayanth Panyam's lab, wanted to share the exciting news of her marriage to Junhuang Jiang on May 20th, 2021! They are both currently studying in the College of Pharmacy at the University of Texas- Austin. While the ceremony was simple, due to the pandemic, they plan to hold the reception sometime later and look forward to inviting all of their friends and family to come

Manish Mishra, a former postdoctoral associate in Dr. Calvin Sun's lab, was recognized as an Outstanding Reviewer-2020 for CrystEngComm. In 2020, he reviewed 16 papers for CEC.

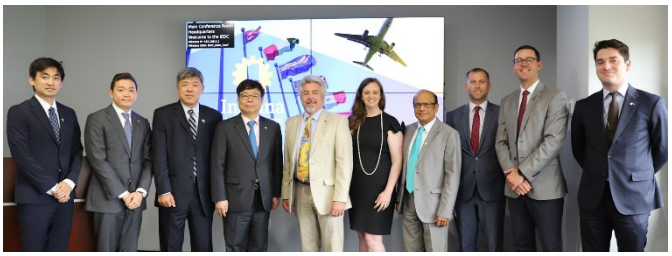
Milestones

Life updates from students, staff, and alumni

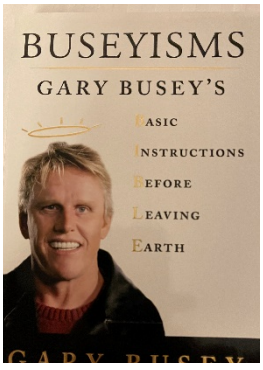
Makarand (Mak) Jawadekar, a 1982 Pharmaceutics PhD graduate in Ed Rippie's lab, is serving as the Chief Advisor to Polus Inc., a Korea-based CDMO company. The Korean team visited the US at the same time South Korean President Moon Jae-In visited President Biden on May 21st. Later in May, Mak introduced Polus Inc. and its team to Indiana Governor Eric Holcomb at the invite of Mak's dear friend, Indiana Attorney General Todd Rokita. The introductory meeting outlined Polus Inc.'s plans to manufacture mRNA vaccines and COVID-19 rapid test kits for Indiana in 2022.

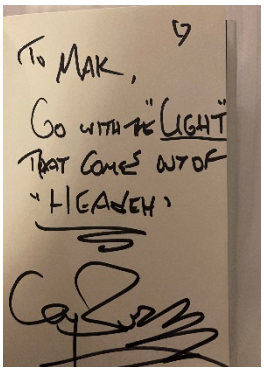


Governor Holcomb then arranged for the Polus Inc. team to meet with the Eli Lilly executive team, including the Eli Lilly CEO David Ricks. Eli Lilly has expressed desire to work with Polus Inc. as Eli Lilly is headquartered in Indianapolis, Indiana.



The adjacent photos include Indiana Governor Eric Holcomb, the Polus Inc. Korean team, Eli Lilly executives, and members of the Indiana Economic Development Council. In the photo with Governor Holcomb (wearing masks), Gov. Holcomb is proudly showing a photograph from the previous year, when he had invited actors Christian Bale and Matt Damon (stars of the 2019 American sports drama, "Ford Vs. Ferrari ") to attend the INDY-500 race, which Gov. Holcomb hosts every year. Next year, Gov. Holcomb has invited Mak along with his very dear friend, Tonino Lamborghini, Chairman of the Lamborghini empire from Bologna, Italy, to join him at the INDY-500 Race on May 29th 2022. Excitingly, Lamborghini has accepted the invite! On a personal achievement note, Mak was also able claim victory in the US Open tennis finals competitive challenges in East Lyme.





In the world of Pharmaceutics, you never know who you'll meet!

Milestones

Life updates from students, staff, and alumni

Bhushan Munjal, a postdoctoral associate in Dr. Raj Suryanarayanan's lab, published the following:
1. Seema Thakral, Jayesh Sonje, Bhushan Munjal, Raj Suryanarayanan; Stabilizers and their interaction with formulation components in frozen and freeze-dried protein formulations, *Advanced Drug Delivery Reviews*, Volume 173, 2021, Pages 1-19.
2. Bhushan Munjal, Raj Suryanarayanan; Applications of synchrotron powder X-ray diffractometry in drug substance and drug product characterization, *TrAC Trends in Analytical Chemistry*, Volume 136, 2021, 16181.
He also gave a webinar titled, "Interplay of Formulation Components on Excipient Functionality During Lyophilization" on Feb 25, 2021 to SP Industries, Inc.
Additionally, Bhushan gave a presentation titled, "Arginine salts as stabilizers in lyophilized protein formulations" at the IPRIME (Industrial Partnership for Research in Interfacial and Materials Engineering) annual meeting held August 3-5, 2021.

Purnanand Sarma, a 1992 PhD alum, received the prestigious Lifetime Achievement Award from TiE Global, which is a nonprofit organization devoted to entrepreneurs in all industries, at all stages, from incubation, throughout the entrepreneurial lifecycle. Sarma serves as the President and Chief Executive Officer of Immunome, Inc., a biopharmaceutical company utilizing a proprietary human memory B cell platform to discover and develop first-in-class antibody therapeutics, with a focus on oncology and infectious diseases including COVID-19. For more information about the award, please visit: https://indianewengland.com/2020/12/serial-entrepreneur-purnanand-sarma-to-receive-tie-boston-lifetime-achievement-award/

Suneel Rastogi, a 2000 PhD graduate from Dr. Raj Suryanarayanan's lab, joined Applied Materials as Product Marketing Director. Applied Materials is a leading semiconductors company located in Santa Clara, CA. In recent years, the company is exploring the applications of semiconductor technologies in other areas including pharmaceuticals. As a part of the new business development group, Suneel works with external partners including large Pharmaceutical companies to understand their development and manufacturing challenges and provide unique solutions based on well-established semiconductor technologies. Being one of the few employees with a pharmaceutical background, Suneel also guides their team internally in matters related to pharmaceutical development and regulatory expectations.
His elder daughter Shreya graduated from high school this summer. She is excited to join Purdue University in the Integrated Business and Engineering program.

Jayesh Sonje, a graduate student in Dr. Raj Suryanarayanan's lab, gave several invited talks over the course of 2021. The first was to present his research on 'In Situ Investigation of Freeze-Thaw Induced LDH Aggregation in Sodium Phosphate Buffer using Neutron Scattering,' to the AAPS Biopharmaceutical Product Attributes and Biological Consequences Community (BPABC) in January 2021 (virtual event). In April 2021, Jayesh was invited to give a Lyolearn webinar hosted by SP scientific on 'Role of organic co-solvents (t-butanol) in frozen and freeze-dried formulations' (approximately 70 attendees). Jayesh also served as Vice president for the Council of International Graduate Students (CIGS) from Fall 2020 to Summer 2021.

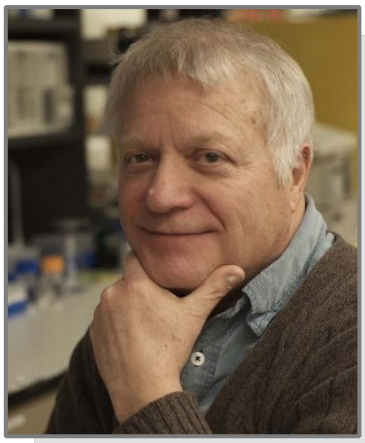
Seema Thakral, a former postdoctoral associate in Dr. Raj Suryanarayanan's lab, published the following:
1. Thakral, S., Sonje, J., Munjal, B. and Suryanarayanan, R., 2021. Stabilizers and their interaction with formulation components in frozen and freeze-dried protein formulations. *Advanced Drug Delivery Review*s.
2. Thakral, S.* and Kim, K., 2020. Small-angle scattering for characterization of pharmaceutical materials. *TrAC Trends in Analytical Chemistr*y, p.116144.

Jody Tracy, Program/Project Specialist for Pharmaceutics and Clinical Affairs, is celebrating her 7th year with the College of Pharmacy and her 13th year with the University of Minnesota. This year, she has transitioned to mostly working from home. In her spare time, she is currently studying the use of Python and R for the visualization of statistical data, and copyediting fiction books for friends. Additionally, Jody and her husband, P.J., adopted a 12-year-old cat, Lola, in July 2021.

Faculty NewsRoom

Activities and Updates

Professor William Elmquist



Dr. Elmquist recently won the 2020-2021 Distinguished Teaching Award. The award was established in 1999 to "recognize [outstanding] contributions to graduate and professional education. Recipients are chosen for excellence in instruction; involvement of students in research, scholarship, and professional development; development of instructional programs; and advising and mentoring of students." Dr. Elmquist will be inducted into the Academy of Distinguished Teachers and carry the designation of Distinguished University Teaching Professor throughout his career at the University of Minnesota. Additionally, his name will be engraved in the Scholars Walk as a Distinguished University Teaching Professor.

He has also given the following invited presentations:

- *Heterogeneity in Transport Mechanisms at the BBB: A critical determinant of efficacy in brain tumors.* Given at the 17th Key Symposium: The Blood-Brain Barrier: Key to Brain Health and Disease in Stockholm, Sweden in August 2021.
- *Factors Leading to Heterogeneity in Drug Delivery to the CNS: Focus on Brain Tumors.* Given at the 3rd BBB Summit in June 2021.
- *Predicting CNS Distribution of Panobinostat in DIPG.* Given at the 2021 SNO Pediatric Neuro-Oncology Research Conference in June 2021.
- *Factors influencing drug transport at the BBB: A critical determinant of efficacy in brain tumors.* Given during the Ivy Foundation Brain Tumor Seminar Series in November 2020.

Associate Dean and Professor Carolyn A. Fairbanks

Professor Carolyn Fairbanks is in her fourth year as Associate Dean for Research for the College of Pharmacy and her second year as the Associate Dean of Graduate Education. Dr. Fairbanks serves as Chair of the Council of Research Associate Deans of the University of Minnesota and she represents the CoP to the Graduate Education Committee. She also serves on the Opioid Advisory Task Force of the University of Minnesota and co-leads the U of M Pain Consortium (pain.umn.edu) which is supported by a generous gift from the Hubbard Family Foundation which is matched with support from the Office of the Vice-President for Research, the Office of Academic Clinical Affairs, and the Medical Discovery Team on Addiction.

In 2021 she continued her service to the Somatosensory and Pain Systems (SPS) Study Section which reviews research applications on pain, analgesia and somatosensory systems in animals and humans. She also reviews grant applications for the Blueprint Neurotherapeutics Network (BPN): Small Molecule Drug Discovery and Development for Disorders of the Nervous System initiative. In 2021 Dr. Fairbanks became the Chair of the Neuropharmacology Division of the American Society of Pharmacology and Experimental Therapeutics (ASPET).

In 2021 Dr. Fairbanks and her team continued working on the award that she received in 2019, a $4.5 million grant from the Department of Defense Congressionally Directed Medical Research Program for their project, titled “Therapeutic Development of Non-Opioid Strategically Substituted Agmatines for Chronic Pain Management”. The program has been facilitated with contributions by Gunda Georg (Department of Medicinal Chemistry and the Institute for Therapeutics Discovery and Development (ITDD)) and Sudhakar Jakkaraj (Institute for Therapeutics Discovery and Development). 2021 also brought two separate and new analgesic development collaborations with Dr. Vadim Gurvich of ITDD and Dr. Swati More of the Center for Drug Design. Dr. Fairbanks and her colleagues are laser focused on finding new safer analgesic medications and are working toward a future where addiction is no longer a public health crisis and where all people with pain receive safe and effective care. Overall, 2021 was a great year for our research enterprise and 2022 is forecasted to be exceptional! 2021 holds great promise for a bright future for our research enterprise!

Professor Karunya Kandimalla

Dr. Karunya Kandimalla's lab continues to focus on developing experimental methods and models to elucidate macromolecular transport at the blood-brain-barrier (BBB). In collaboration with Dr. Ling Li (Experimental and Clinical Pharmacology, UMN), the Kandimalla Lab has been investigating the efficacy of HDL mimetics as potential therapeutic agents for Alzheimer's disease (AD). With Drs. Val Lowe, Ronald Petersen, and David Knopman (Mayo Clinic, Rochester, MN), the Kandimalla Lab has been investigating insulin trafficking deficiencies at the BBB in AD patients and elderly individuals. With Dr. Krishna Kalari (Mayo Clinic, Rochester, MN), they are developing 'omics' approaches to investigate pathophysiological mechanisms contributing to BBB dysfunction in AD and cerebrovascular disease. In addition, the Kandimalla Lab has been developing novel drug delivery systems to administer via transdermal (pain), nasal (epilepsy), or otic (otitis media) routes, was interviewed by Allen Saakyan of the YouTube series "Simulation" on the connections between metabolic syndrome, including cardiovascular diseases and diabetes, and Alzheimer's disease. You can view the interview at z.umn.edu/Simulation367.

Professor Hongbo Pang

Dr. Hongbo Pang welcomed M. Mahadi Hasan, Ph.D. to the lab in May as a postdoc scholar. Dr. Hasan received his PhD at Kyoto Pharmaceutical University in 2018 and had been a Japan Society for the Promotion of Science Postdoctoral Fellow before joining Dr. Pang's University of Minnesota lab. Dr. Hasan's specialty is transdermal delivery assisted by low electric current.

Two new masters students, Nianwu Wang and Jiaqi Zhao, also joined the lab this fall.

Additionally, the Pang lab is hosting rotation students from Departments of BME and Pharmacology.

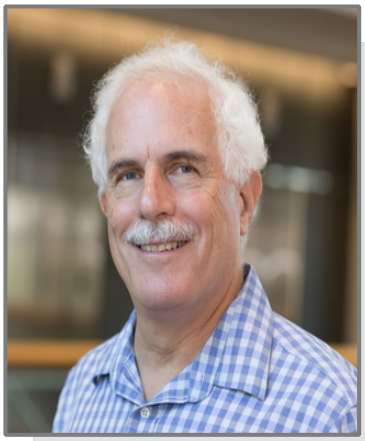
Jibin Guan, Ph.D., after being in the lab for two and a half years, decided to take a position at the Mass Spec facility at the Masonic Cancer Center.

In September, Dr. Pang was invited to give a departmental seminar to the Department of Pharmaceutics and Pharmaceutical Chemistry at the University of Utah. Additionally, over the course of 2021, Dr. Pang has been invited to give seminars in the departments of Biomedical Engineering, Pharmacology, MICaB and BMBB graduate programs, and the phagocyte interest group at the University of Minnesota.

Publications:

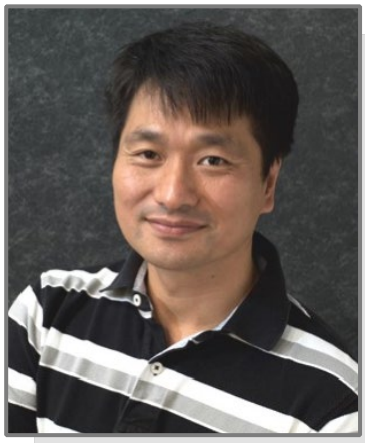
A couple of our studies have been published at Advanced Functional Materials (co-first authors: Jibin Guan and Hong Guo), Nanoscale (co-first author: Yushuang Wei) and Pharmaceutics (first author: Yuexuan Li). Another manuscript is under revision at Advanced Science (first author: Xian Wu) as of Oct 21.

Professor Ronald A. Siegel



Dr. Ronald A. Siegel continues as Interim Department Head in the Pharmaceutics Department, and also continues to direct the Biomaterials and Pharmaceutical Materials (BPM) program for Industrial Partners for Research in Interfacial and Materials Engineering (IPRIME).

Professor Changquan Calvin Sun



Dr. Sun was invited to join the Editorial Advisory Boards of CrystEngComm

and AAPS Open. He has continued to serve on the Editorial Advisory Boards of Crystals, Int. J. Pharm., J. Pharm. Sci. Mol. Pharmaceutics, and Pharmaceutical Research.

Editor: Chemical and Pharmaceutical Bulletin

Guest Editor: Pharm. Res. On a special issue "Crystal and Particle Engineering"

Professional committees

10/2021 – 02/2022, Member, Organizing committee for "Early Career International Particle Technology Forum 2022" (virtual) by UK Annual Particle Technology Forum

10/2020 – 06/2021, Chair, 5th David Grant Symposium, University of Minnesota

05/2021 – 06/2022, Session Chair, Crystals in Nature and Medicine, 25th International Conference on the Chemistry of the Organic Solid State (ICCOSS XXV)

12/2020 – present, member, International Steering Committee for the Handbook of Pharmaceutical Excipients (10th edition), published by the Pharmaceutical Press and AphA

Invited presentations

December 3, 2021, Engineering Mechanical Properties of Drugs for Successful Tableting, Special session of International Conference on Advanced Materials and Mechanical Characterization (ICAMMC 2021) "Crystal Engineering: Mechanical properties of organics"

Oct. 14, 2021, Challenges and Opportunities in Optimizing Mechanical Properties of Drugs by Incorporating Excipients, Pharmaceutical Crystallization Summit

Oct. 5, 2021, Enhancing Pharmaceutical Properties of Drug through Spherical Crystallization, CatSci Symposium "The Next Decade of Drug Development" (Virtual)

August 14, 2021, Pharmaceutical Cocrystals for Tablet Development (Virtual), in "Multi component solids: opening new avenues for Pharmaceutical Industry", Department of Pharmaceutical Sciences and Technology, Birla Institute of Technology, Mesra, Ranchi, India

June 23, 2021, Compaction Simulation – A Useful Tool for Tablet Development, 5th David Grant Symposium, University of Minnesota, Minneapolis, MN (Virtual)

June 18, 2021, Enabling Tablet Development through Crystal Engineering, Virtual Midwest Organic Solid-State Chemistry Symposium (V-MOSSCS), University of Iowa, Iowa City, Iowa

May 24, 2021, C. Wang and C.C. Sun, Computational Prediction of the Elastic Constants of Molecular Crystals, 2nd Annual Virtual Symposium on Solid-State Organic Chemistry (VS3OC), Organized by Merck and New York University

April 15, 2021, Material sparing and expedited development of tablets - A materials science based QbD approach (Virtual), New Jersey Pharmaceutical Association for Science and Technology (NJPhAST), New Jersey, NJ

April 13, 2021, Material-sparing and Expedited Development of Tablets for Early Clinical Testing, Advances in Drug Formulation & Delivery (Virtual), Bioduro, San Diego, CA

January 9, 2021, Applications of nanoindentation in solid form engineering and tablet formulation, Mini Symposium: Nanomechanics for Organic Crystals and Pharmaceutical Applications (via Zoom), Indian Institute of Science Education and Research (IISER) Kolkata, India

January 2, 2021, Preparation and Applications of Pharmaceutical Co-crystals, Virtual Symposium "Role of Multi-Component System in Pharmaceutical Formulation Development", Department of Pharmaceutical Sciences, Saurashtra University, Rajkot, India

Patents

C.C. Sun and C. Wang, Amorphous solid dispersion of sorafenib and solid formulation comprising the same, (2021) U.S. Pat. Appl. 63/219,934

X. Zhao, X. He, C. Wang, C.C. Sun, S. Hu, A method for preparing ligustrazine-acesulfame monohydrate and its characterization (2021) CN 108947917 B

X. He, X. Zhao, S. Hu, C.C. Sun, C. Wang, A method for preparing ligustrazine-saccharine monohydrate and its characterization (2021) CN 108892644 B

Professor Raj Suryanarayanan

Dr. Raj (Sury) Suryanarayanan's lab continues to apply principles of pharmaceutical materials science to the design of robust pharmaceutical dosage forms with reproducible and predictable properties.

Invited Lectures at Scientific Org Meetings

- "The role of excipients in drug delivery", PHARMATECH 2020 – Exploring Myriads of Pharma in Pharmaceutics and Pharmaceutical Technology, organized by the All India Council for Technical Education (AICTE) and the Indian Department of Science and Technology: the Gujarat Council on Science and Technology (DST-GUJCOST), October 28, 2020 (remote conference).

Invited Lectures at Universities Pharmaceutical Companies

- "The role of excipients in drug delivery", presented at PHARMATECH 2020 – Exploring myriads of Pharma in Pharmaceutics and Pharmaceutical Technology, sponsored by AICTE and GUJCOST-DST, October 28, 2020 (online).

- "Role of excipients in efficient drug delivery", presented to the Integrated Product Development Organization, Dr. Reddy's Laboratories, Hyderabad, India, February 23, 2021 (online).

- "Role of excipients in efficient drug delivery", presented to the Amgen Seminar Series in Chemical Engineering, sponsored by Amgen and the Department of Chemical Engineering at the University of Rhode Island, March 11, 2021 (online).

- "Amorphous solid dispersions - design, characterization and stability prediction", presented at the Global Analytical Development Conference (GADC) across Sandoz Development Centres (SDC) on March 16, 2021 (online).

- Participant in the Roundtable Discussion, "Polymorphs Throughout the Pharmaceutical Development Lifecycle" at Pharmanalytical Summit 2021: A Virtual Forum presented by Rigaku on March 26, 2021 (online).

- "Excipient phase behavior in frozen and freeze-dried systems – potential implications on drug stability", presented at the 5 th Annual David J.W. Grant Symposium in Minneapolis, MN, June 21-23, 2021.

Professor Timothy Wiedmann

Dr. Wiedmann assisted Dr. Nikki Johnston at Milwaukee Medical College to advance inhalation therapy for the treatment of laryngeal inflammation using AeroCore facilities, an internal/external research organization at the University of Minnesota. Support was also provided for the last year of the five-year project with Dr. Stephen Hecht, *e-Cigarettes: Formaldehyde DNA Adducts, Oxidative Damage, and Potential Toxicity and Carcinogenesis*. In the spring of 2021, Dr. Wiedmann spent two months at Kaohsiung Medical University, Kaohsiung, Taiwan (ROC) collaborating with Dr. Ming Wu's laboratory in designing/constructing an inhalation system to explore the basis of the gender difference in cancer incidence arising from exposure to cooking oil fumes.

Dr. Wiedmann continues to work with Dr. Amir Naqwi, Abbe Vision where a high efficiency exposure system was developed and tested for rodent animal models (Funded proposal: *Tools for Improved Translation of Novel Inhalable Therapeutics*). A remarkable 60% of the compound introduced to the system was deposited in the lungs of mice, which contrasts with other systems where less than 1% is utilized. He has also become more involved in Dr. Naqwi's project testing the use of a spray system for lung regeneration.

This year, Dr. Wiedmann served as co-adviser to Chenxu Li and Fangyi Dong, who graduated with Pharmaceutics MS degrees 2021 and currently co-advises MS students, Zijian Wang (Pharmaceutics), and Stephanie Eilts (Mechanical Engineering). Dr. Wiedmann continues his phase retirement, which is planned to extend for the last year at 25% FTE with complete retirement at the end of June 2023.

Recent Publications

Publications: Dr. Carolyn Fairbanks

Griffith JI, Kim M, Bruce DJ, Peterson CD, Kitto KF, Mohammad AS, Rathi S, Fairbanks CA, Wilcox GL, Elmquist WF. CNS Distribution of an Opioid Agonist Combination with Synergistic Activity. J Pharmacol Exp Ther. 2021 Oct 18:JPET-AR-2021-000821. doi: 10.1124/jpet.121.000821. Epub ahead of print. PMID: 34663676.

Peterson CD, Kitto KF, Verma H, Pflepsen K, Delpire E, Wilcox GL, Fairbanks CA. Agmatine requires GluN2B-containing NMDA receptors to inhibit the development of neuropathic pain. Mol Pain. 2021 Jan-Dec;17:17448069211029171. doi: 10.1177/17448069211029171. PMID: 34210178; PMCID: PMC8255568.

Pflepsen KR, Peterson CD, Kitto KF, Riedl MS, McIvor RS, Wilcox GL, Vulchanova L, Fairbanks CA. Biodistribution of Adeno-Associated Virus Serotype 5 Viral Vectors Following Intrathecal Injection. Mol Pharm. 2021 Oct 4;18(10):3741-3749. doi: 10.1021/acs.molpharmaceut.1c00252. Epub 2021 Aug 30. PMID: 34460254; PMCID: PMC8519182.

Belur LR, Romero M, Lee J, Podetz-Pedersen KM, Nan Z, Riedl MS, Vulchanova L, Kitto KF, Fairbanks CA, Kozarsky KF, Orchard PJ, Frey WH 2nd, Low WC, McIvor RS. Comparative Effectiveness of Intracerebroventricular, Intrathecal, and Intranasal Routes of AAV9 Vector Administration for Genetic Therapy of Neurologic Disease in Murine Mucopolysaccharidosis Type I. Front Mol Neurosci. 2021 May 10;14:618360. doi: 10.3389/fnmol.2021.618360. PMID: 34040503; PMCID: PMC8141728.

Publications: Dr. William Elmquist

Griffith JI, Sarkaria JN, Elmquist WF. Efflux Limits Tumor Drug Delivery Despite Disrupted BBB. (2021). Trends Pharmacol Sci. 2021 Jun;42(6):426-428. doi: 10.1016/j.tips.2021.03.001. Epub 2021 Mar 15.

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