

UNIVERSITY OF CALIFORNIA, RIVERSIDE

UNDERGRADUATE RESEARCH JOURNAL

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FROM THE CHANCELLOR



As a research university, one of UC Riverside's most important duties is the creation of knowledge. Undergraduate research is a hallmark of UCR's scholarly and educational missions and a factor in our university's impressive trajectory.

With faculty-mentored research projects across a breadth of disciplines, UCR provides a wealth of opportunities for students to investigate complex questions and discover the joys of scholarly research.

As you will see in this 17th volume of the *UC Riverside Undergraduate Research Journal*, our students are making the most of these opportunities and accomplishing truly inspiring work. The scholarship that appears each year in this publication represents research excellence and creative endeavors of the highest order. UCR is at the forefront of discovery, with a world-class faculty, including two Nobel laureates, and state-of-the-art instructional and testing laboratories. UCR is creating a home for students, faculty, and community members to collaborate, test, and learn.

At UCR we are stewards of transformation; it is in our DNA to ensure that we create an environment and structure that fosters innovation to solve our community and world's greatest challenges. I am impressed by the dedication and innovation displayed by the students and their mentors in pushing forward in research despite the challenges faced by the pandemic.

I congratulate all the students who contributed to this edition of the Journal, and I express my sincere gratitude to the faculty mentors and staff members that supported these students in their scholarly endeavors.

Sincerely,

A handwritten signature in blue ink, which appears to read "Kim A. Wilcox". The signature is fluid and cursive, written on a white background.

Kim A. Wilcox
Chancellor

FROM THE VICE PROVOST AND DEAN, UNDERGRADUATE EDUCATION

Engaging with research is about discovery in two important ways. First, in the university context, students are often encouraged to engage with research as they explore and discover their specific areas of scholarly interest. A student's area of research interest may be sparked within the context of a class, learning about a professor's research area through a lecture or during office hours, or by exploring the published literature on a topic. For others, discovery and engagement with research might be inspired by an issue, topic, or problem they would like to solve in the world or a community they care about and wish to serve.

Secondly, the theme of discovery through research is also about the researcher—engaging in inquiry, question-asking, data-generation, and thinking about ways the work might impact the audience or topic being explored. This was certainly the case for me. I was introduced to research about halfway through my undergraduate student experience. As a first-generation college student this was perhaps one of the most formative experiences of my college career. I explored the factors that contributed to high school student success, and this experience helped me discover my identity as an emerging researcher. Equally important to my identity as a researcher was my involvement in the honors program, my summer conducting research with a professor at another university, and my experiences as a McNair Scholar. I saw first-hand how engaging with research helps facilitate discovery in so many important ways.

To a large degree, this volume of published work in the *UCR Undergraduate Research Journal* reflects discovery by our students who have demonstrated a commitment to inquisitiveness, knowledge creation, and now, knowledge dissemination. The student-authors in this volume serve as a reminder that engaging with research is both an individual commitment to a goal but also an endeavor that is likely supported by a faculty mentor, a community, and a community of researchers that helps facilitate a student's success. Finally, this volume serves as an inspiration to researchers everywhere, some of whom may have inspired the work represented in this volume, and those future student-researchers who may be at the beginning stages of their own research journeys.

Congratulations to all of the contributors in this important volume!



Louie F. Rodriguez
Vice Provost and Dean, Division of Undergraduate Education
Professor of Education



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Mahnur Bharucha
Editor-in-Chief
Biological Sciences

It is with great pleasure that we present UC Riverside's 17th edition of the *Undergraduate Research Journal*. We have had the honor of collaborating with emerging minds across campus in developing this publication. It is the collective efforts of everyone involved and the time they provide that ensures the continuation of this journal with standards that reflect the excellence that UCR represents. Congratulations to the authors for your commitment—your courage to put your ideas out for criticism and refinement in an environment unfamiliar to many of us. Doing so is commendable and serves as a testament to the community of scholars you have worked with. Your achievements, found in this 17th edition, will forever be a part of the Journal's legacy. Congratulations are also due to the Student Editorial Board and Faculty Advisory Board—your diligence and dedication to the publication process have ensured the quality and success of the Journal. We are remarkably grateful to have been part of the outstanding team that made this edition possible.

Sincerely, Mahnur Bharucha and Andrew Martin, Co-EIC's



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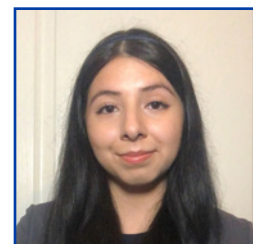
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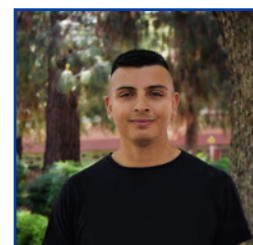
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Since *UCR's Undergraduate Research Journal* started 17 years ago, it has published over 165 scholarly articles across many fields. These papers represent the commitment of our undergraduate students to performing independent research as part of their undergraduate experience. Because undergraduate research can often form part of a larger work with many contributors, the importance of the student's contribution can sometimes be lost. With

the *Undergraduate Research Journal*, students can publish their work as first authors before the end of the academic year through a peer-review publication process. The paper becomes a part of

students' professional experience, contributing to their record of scholarly achievement. The Journal's submission and review process is run by undergraduates who form the Student Editorial Board, working with members of the Faculty Advisory Board. We owe a debt of gratitude to these students for their professionalism and dedication to the review and preparation of the articles in this issue. We are also grateful for the participation of the members of the Faculty Advisory Board in guiding the reviewers. I would like to thank Gladis Herrera-Berkowitz for her work in supporting and guiding the process every year, Lisa Des Jardins for providing Graphic Design assistance, Jennifer Kavetsky for her support of our authors, as well as Undergraduate Education for their funding support. If you are interested in publishing your undergraduate research at UCR, consider submitting to our next issue!

Prof. Morris F. Maduro
Chair of the Undergraduate Research Journal
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Professor of Biology

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ABOUT THE COVER



**Victoria Van
Hulle**

Victoria Van Hulle is majoring in Neuroscience and will be a Junior in Fall 2023. She graduated from Riverside STEM Academy High School in 2021. In her junior year, she plans to get involved in the incredible research opportunities that UCR has to offer. Her love for photography started at a very young age and has blossomed over time. She enjoys taking photos at the UCR Botanical Gardens in her free time.

Hummingbirds are tiny magnificent flying birds symbolizing joy, beauty, spirits, and angels. They are an inspiring sign of hope and good luck. I had the opportunity one Spring day at the University of California, Riverside Botanical Gardens to capture a hummingbird in flight. This beautiful hummingbird had a green and blue jewel-like body along with iridescent wings and was delightful to watch. I took many pictures of the hummingbird I named Annie hovering over a red flower from the Chuparosa plant. I got a beautiful view of Annie's iridescent pearl-like wings as the sun reflected through them.