

## **Cover Art - ‘A Reemerging Light’**

One year ago, all normal functions in the world came to a startling halt, undergraduate research being no exception. The students walking within an empty UCR campus serve as a reminder of the pandemic and the individuals who were able to navigate research during these difficult times. As the world recovers and returns to a “new normal,” so too does UCR, persevering against the challenges of COVID-19 under the welcome light of a new day.

~Co-Editors, Shaiva Patel & Ethan Tanchoco

Photo taken by Stan Lim, UCR Communications, 2020

# UNDERGRADUATE RESEARCH JOURNAL

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## FROM THE CHANCELLOR



The word *resilient* is having a moment. Over the last year, as we rode waves of obstacles and changes, much has been written about the human spirit and our ability to continue forward in the face of adversity. Resilient certainly describes the students and mentors who forged a path forward in undergraduate research during an immensely challenging year.

*Impressive* is another relevant description. To complete research projects, then collaborate remotely to finish and submit articles for this year's *UC Riverside Undergraduate Research Journal*, required an impressive level of creative thinking and dedication. This reveals an underlying passion and commitment to scholarship and development of new knowledge. As you will find, the work itself is also impressive.

At UCR, we strive to prepare our students for what's now and what's next so they may be future fluent, ready to tackle the world's evolving challenges. The research articles

published in this journal provide a glimpse of the opportunity our students embody.

To all of the students who contributed to this year's journal, congratulations on your outstanding work. I am incredibly grateful to the faculty mentors and staff members whose dedication, guidance, and perseverance made these projects possible. All of your efforts inspire pride in our university and strengthen our hope for the future.

Sincerely,

A handwritten signature in blue ink that reads "Kim A. Wilcox". The signature is written in a cursive, flowing style.

Kim A. Wilcox  
Chancellor

# FROM THE VICE PROVOST AND DEAN, UNDERGRADUATE EDUCATION

The COVID-19 pandemic changed all of our lives, halted most research, and delayed valuable learning experiences for undergraduates. However, the pandemic did not prevent student, faculty, and staff creativity and ingenuity in finding new and innovative methods of continuing to contribute to their fields of study. Undergraduate researchers and their faculty mentors demonstrated flexibility in adjusting their research and creative methods to accommodate social distance guidelines. Their contributions may have followed a different process, but they continued. The student researchers whom are presenting their work in the following pages demonstrate resiliency in tackling the local challenges that face California's Inland Empire as well as the dynamic and emerging challenges facing humanity.

Participating in original research and creative activities always takes courage: the courage to challenge assumptions, admit a lack of knowledge, and persist through the inevitable setbacks and obstacles of expanding our shared understanding of the world. This year's scholars conducted their research during a time of national turmoil and unrest, and so they are doubly courageous. They had the tenacity to build connections – social, intellectual, and empathetic – when so much of the country was struggling. We must applaud them all and find both comfort and our own courage in knowing that these researchers represent the best and brightest of our shared future.

The Fifteenth Edition of the *University of California, Riverside Undergraduate Research Journal* features some of the best faculty-mentored undergraduate research and scholarship, adding to the university's 67-year legacy. Thank you to our students, faculty, and staff who made the publication of the Undergraduate Research Journal possible. A special thanks to the Student Editorial Board for leading the peer-review process, the Faculty Advisory Board for its consultation and advice, and the staff of Student Engagement for their roles in bringing this journal to fruition.

I hope you are enriched and encouraged by the discoveries revealed in this year's Undergraduate Research Journal.

Wishing you all the best,



Jennifer Brown, Ph.D.  
Vice Provost and Dean of Undergraduate Education  
Professor in the School of Public Policy



# UNDERGRADUATE RESEARCH JOURNAL EDITORIAL BOARD



**Shaiva Patel**  
Editor-in-Chief  
*Biology, Spanish Minor*

It is with great pleasure that we present UC Riverside's 15th edition of the Undergraduate Research Journal. We have had the honor of collaborating with brilliant minds across campus in bringing this publication to fruition during such an unprecedented year. It is the collective efforts of everyone involved that ensures the integrity and standards of the Journal reflect the excellence that UCR represents. Congratulations to the authors for your commitment — your ability to adapt to a remote environment, one that is not conducive to traditional undergraduate research, is commendable and serves as a testament to UCR's academic and creative culture built upon the pursuit of knowledge. Your achievements found in this 15th edition will forever be a part of the Journal's legacy. Congratulations also 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,

Shaiva Patel & Ethan Tanchoco, Co-Editors-In-Chief



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Since UCR's *Undergraduate Research Journal* started 15 years ago, it has published over 160 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 and publication process. The paper becomes a part of a student's 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 the students for their professionalism and dedication for 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 this year, 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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