THE UNIVERSITY OF ARIZONA
Ecosystem Genomics

CONVERGENCE INSTITUTE WORKSHOP REPORT MAY 13-15, 2024

Building Resources for InterDisciplinary training in Genomic and Ecosystem Sciences

THE UNIVERSITY OF ARIZONA
Ecosystem Genomics
Graduate Interdisciplinary Program

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Executive Summary

Statement of Purpose

One purpose of the Third Annual Ecosystem Genomics Convergence Institute in May 2024 was to introduce participants, including a cohort from Auburn University's NSF Research Traineeship (NRT) as well as members of the University of Arizona community, to interdisciplinary collaboration in ecosystem, genomic, and climate sciences. Another purpose was to provide University of Arizona graduate students who are part of the Building Resources for Interdisciplinary Training in Genomic and Ecosystem Sciences (BRIDGES) NRT and the Ecosystem Genomics Graduate Interdisciplinary Program (ECGN GIDP) with an opportunity to present on upcoming and completed summer research experiences.

What is Ecosystem Genomics?

Ecosystem Genomics seeks to to understand the interaction between information encoded in genes and ecosystem processes. By investigating how to scale from genes to ecosystems, and how ecosystems select for and influence genomic composition, we can improve understanding and prediction of how natural and managed systems function and respond to change.

The University of Arizona's Ecosystem Genomics Initiative includes the BRIDGES NRT program and the ECGN GIDP. Graduates enrolled in the ECGN GIDP can earn Graduate Certificates or PhD Minors in Ecosystem Genomics and is the sustainability piece of the BRIDGES NRT.

The primary goal of the BRIDGES NRT program is to address a significant challenge in modern biology: scaling from genes to ecosystems and vice versa. Recognizing the communication barriers between genomic and ecosystem scientists due to vastly different disciplinary cultures, the program aims to integrate social science perspectives to understand and bridge these differences. This innovative approach will enhance interdisciplinary collaboration and emphasize inclusive excellence by fostering diversity among students across scientific and demographic lines. Ultimately, the program seeks to enable these diverse scholars to tackle real-world problems, such as the impact of

microorganisms on climate change and the development of sustainable agroecosystems for a growing global population.

General Components of the Institute

The Ecosystem Genomics Convergence Institute, a unique learning opportunity, commences each year with a pre-session on a topic or topics identified by BRIDGES NRT and GIDP students as important to their development. Past topics include Data Skills, Grant Writing, Research Conduct. The first day typically includes a Welcome, followed by a Plenary Panel speaking on the Challenges of Ecosystem Genomics. This portion of the institute wraps up with presentations by the BRIDGES NRT social scientists on the Culture of Science. The next segment of the institute includes BRIDGES NRT and Ecosystem Genomics student presentations grouped by theme. Students in year one, present on their upcoming summer research. Those in year two, present on their completed Ecosystem Genomics research for peer and faculty feedback. The final portion of the institute is split into two tracks, with faculty, staff, and advisory board members participating in focus groups (students have their focus group earlier in the institute) and learning about program successes from leadership and the external evaluator. The second track is focused on professional development for BRIDGES NRT and ECGN GIDP, but many of the sessions are open to anyone interested. Past sessions have included discussions on Science Communication to the General Public, Stereotype threat, research conduct, and financially supporting research. The institute ends with a closed session with BRIDGES NRT and ECGN GIDP students and program leaders and students wrapping up year two receive certificates of completion.

Objectives

To address program challenges, the BRIDGES NRT participants, representing multiple cohorts from both the University of Arizona and Auburn University, along with ECGN students, spent three days learning about the collaborative aspects of convergence research through sessions and presentations on the science of team science, cultures of science, and societal impact. Prepared with the best practices of collaborative convergence research, the core of the institute features student presentations on the broad themes. These presenters aimed to receive feedback, cross-learn, and build

networks of interdisciplinary scientists ready to address society's complex challenges. In addition to student presentations, the institute hosted a plenary keynote session on Challenges of Ecosystem Genomics, updates, and shared learning in the NRT in the form of focus groups, reporting, and evaluation, as well as information on potentially relevant funding opportunities to advance careers in science.

Institute Overview

The Convergence Institute (13-15 May 2024) was a three-day institute hosted by the BRIDGES NRT program (with additional support from BIO5 Institute) at the University of Arizona (UA) in Tucson, AZ. The institute aims to bring together scholars from Ecosystem Genomics annually. Participants included students and faculty from the BRIDGES NSF Research Traineeship (NRT) program at UA and students from the Climate Resilience NRT from Auburn University. The following sections summarize the proceedings from each institute day: The Convergence Institute Pre-session, the Convergence Institute Part 1, Part 2, and Part 3. For more details on each session or presentation mentioned, please refer to the appropriate subsection in the report.

Day 1: Convergence Institute Pre-Session

The Convergence Institute pre-session, engaged graduate students from BRIDGES and Climate Resilience NRTs, the ECGN GIDP, and from other departments in growing as team scientists through a workshop on interdisciplinary team science and training in appropriate research conduct. These two training courses aimed to prepare the students to effectively engage with the Convergence Institute and improve as interdisciplinary researchers of Ecosystem Genomics.

The first component of the Convergence Institute was an institute on Interdisciplinary Team Science in Action, led by Dr. Anne Mook, a senior team scientist at the Institute for Research in the Social Sciences (IRISS) from Colorado State University. This workshop aimed to explore the dynamics of interdisciplinary collaboration in scientific research in Ecosystem Genomics, focusing on effective communication strategies, building trust, and working in teams. Attendees participated in several activities related to these aims in the institute’s pre-session, provoking discussion, and reflection on their academic journeys and the challenges and opportunities of interdisciplinary science.

Attendees rated the level of interdisciplinary engagement in their work, with the majority indicating that their research draws on different disciplines. Attendees stated that these collaborations include external partnerships with government agencies, industry, farmers, and outreach groups. Participants identified a few challenging experiences they have had working with collaborators. These included communication barriers due to cultural and discipline-specific language differences, navigating different priorities related to research output and publishing, and familiarity with existing research bodies. For instance, time constraints and identifying research gaps across different fields were highlighted as particularly challenging. Participants also pointed out that certain societal constraints, including family obligations and gender roles, can negatively impact one's ability to conduct interdisciplinary work.

Attendees engaged in an in-depth discussion regarding the challenges of communicating with shared language across disciplines and cultures, emphasizing the importance of understanding and respecting diverse perspectives to overcome communication barriers. Participants recognized the significance of communication in successful research collaboration, advocating for equal voice and inclusivity in interdisciplinary teams. To practice using different communication styles in a team setting, participants engaged in a role-playing activity, interviewing other participants with a supportive, disruptive, and neutral interviewing style. Attendees reflected on the pros and cons of utilizing each interview style. Participants shared that a supportive interview style might be more effective for eliciting positive behavioral changes from group members in many cases. Yet, neutral interviewing is helpful when working with two conflicting group members, and disruptive interviewing helps work with combative or difficult group members.

In addition to effective communication, fostering shared trust between team members is a fundamental component of functional collaborative science. Attendees discussed the differences between rational and affinitive models of trust, and each identified which form of trust they relied on most when forming collaborations. These differences underscored the importance of understanding how we trust others and that there are different approaches to building confidence in interdisciplinary teams.

The Interdisciplinary Team Science in Action workshop ended with groups engaging in an activity involving divergent-convergent thinking processes to identify overarching themes in their research areas, first building off each other's opinions of the themes and then creating connections between them. Overarching themes that came to the surface

from this activity were the connection of evolution and ecological genomics, the change of a gene in an organism based on a change in the ecosystem, and the evaluation of the changing climate's impact on an ecosystem using genetic techniques.

Overall, the workshop provided valuable insights into the complexities of interdisciplinary collaboration, highlighting the importance of effective communication, trust-building, and shared understanding. Participants left with a deeper appreciation for the challenges and opportunities of working across disciplines and a commitment to fostering collaborative relationships in their research endeavors.

In the afternoon, BRIDGES students from cohorts I-IV were invited to a closed session to review survey results and give feedback on the NRT with program evaluator Shirley Vincent. The previously taken surveys included questions about how the students felt about the program and their academic units at the beginning of their time in the NRT, and another survey at the end of the year, specifically about how they believed their work fit in as an interdisciplinary study. The surveys also questioned how each student felt about their work and how they belong in the field of interdisciplinary sciences. Shirley Vincent showed the students how their opinions had changed in the first survey compared to their second, with a collective increase in confidence based on some survey feedback.

The pre-session concluded with BRIDGES students synchronously completing the online University of Arizona Responsible Conduct of Research training, which is a requirement for students in the NRT.

Day 2: Convergence Institute Part 1

The second day of the institute marked the official beginning of the Convergence Institute. Dr. Scott Saleska, professor of Ecology and Evolutionary Biology, and Dr. Betsy Arnold, professor in the School of Plant Sciences, co-Directors of the BRIDGES program , gave opening remarks about the field of Ecosystem Genomics. In their introduction to the Convergence Institute and first session, they highlighted that ecosystem and genomic scientists do not have an ideal set of tools for talking to each other to unravel the questions of how genes of organisms play a role in driving higher-order ecosystem functions. Another challenge Ecosystem Genomics faces is the variety of cultures that define the boundaries of our disciplines. The program also focuses on realizing diversity in scientific disciplines, as well as in the demography and

cultures of those who participate in it. The plenary speakers that followed gave seminars that touched on some of these challenges.

The first plenary speaker was Dr. Patrick Sorenson, a Project Scientist at Lawrence Berkeley National Laboratory, followed by Dr. Jana U'ren, a microbial ecology and genetics professor from Washington State University. Each gave short talks on their research as it relates to Ecosystem Genomics. Afterward, they participated in a panel, moderated by Dr. Saleska, further discussing challenges in Ecosystem Genomics. Questions from students included how genomic data can be used for conservation efforts, strategies for integrating genomic research into management of our ecosystems, and how collaboration looks when working in a national laboratory versus in academia at a university.

Part one concluded with presentations from Auburn NRT students. They shared previously made slides that included their research interests, hobbies, and background. They also discussed their increased understanding of Ecosystem Genomics and how it relates to their research.

Day 2-3: Convergence Institute Part 2

After lunch, the BRIDGES and ECGN GIDP students from cohorts II and III gave presentations on their planned or concluded summer research experiences. The first set of presentations centered on "Ecosystem Genomics in a Changing World." These presentations included student research findings on the effects of biochar in the soil, the impact of green infrastructure on soil health, evolutionary responses to climate change in plants of the desert, methane dynamics in the tropics and permafrost-related wetlands, and the thermodynamics of microbial metabolism.

The following round of BRIDGES student presentations centered on "Genomic/Genetic Controls, Arid-Land Organisms." These presentations delved into the methodology and application of genetics and genomics to understand the biodiversity of organisms local to the Sonoran Desert. Presentations covered topics such as collapsing inflated genome assemblies (using a tetraploid *Fouquieria splendens* as a model), identifying genes linked to desiccation resistance in *Drosophila mojavensis*, utilizing fungal herbarium specimens for genetic diversity analysis, and identifying local non-toxigenic strains of Fusarium capable of biocontrol. Each presentation offered valuable insights into addressing the pressing challenges of these disciplines while underscoring the importance of interdisciplinary collaboration and innovative methodologies.

On the second day of the Convergence Institute (workshop day 3), the final set of student presentations centered around “Microbes, Microbiomes, and their Importance in Ecosystem Genomics.” Presentations covered diverse topics such as soil microbial communities’ responses to restoration efforts, plant genotype influence on microbial composition, and microbial dynamics in tropical forest ecosystems. These presentations expanded on research across multiple clades of microbes (fungi, bacteria, and archaea) and how these play shared and divergent roles in ecosystems.

The diverse presentations highlighted the interdisciplinary nature of Ecosystem Genomics and emphasized the importance of collaborative efforts in addressing the complexities of this scientific domain. These presentations spanned scales across biological systems (organisms versus ecosystems) and approaches (genomics versus metagenomics versus metabolomics) yet had a shared orientation toward understanding how climate change impacts ecosystems and how they function.

Day 3: Convergence Institute Part 3

The morning concluded with presentations on the “Cultures of Science” given by Dr. Jennifer Croissant, Associate Professor of Gender & Women's Studies, and Christine Beach, a BRIDGES fellow from the Educational Policy Studies and Practice program. Dr. Croissant gave an overview of the Cultures of Science aspect of the BRIDGES NRT, explaining how they study the students in the BRIDGES program. Christine presented on the interviews with students conducted as a part of the study on Cultures of Science, expanding on the experiences of the BRIDGES students during their time as researchers of interdisciplinary science and highlighting the program's impact on its participants.

Day 3: Convergence Institute Part 4

Following the Cultures of Science presentations, the institute shifted to two tracks. Track one was focused on Ecosystem Genomics staff and faculty and the BRIDGES advisory board (closed sessions). Track two focused on professional development for BRIDGES NRT, ECGN GIDP and other graduate students (some sessions closed).

Track one: BRIDGES and GIDP faculty and staff as well as the BRIDGES advisory board participated in a faculty focus group discussion with the BRIDGES external evaluator Shirley Vincent, where she enlisted feedback on the successes and areas of growth for the BRIDGES program. The next session was a Progress and Recruitment Report by BRIDGES Co-Directors, Betsy Arnold and Scott Saleska. The presentation reported program successes and challenges, followed by their plan to overcome these challenges. The track ended with an evaluation report from Shirley Vincent, reflecting evaluation feedback from the year, including the student focus group on day one of the institute.

Track two: The NRT students (BRIDGES and Climate Resiliency from Auburn) engaged in two professional development workshops. The first of these sessions was conducted by Michelle Higgins, associate director of the Office of Societal Impacts, who led a workshop on developing each student's broader impact identity. The workshop involved critical reflection on who each attendee is as a researcher and what they do as a researcher. These reflections enabled each participant to identify their unique passions and abilities regarding their research and use these to inform how their research will have specific, greater effects.

The second professional development session included presentations and a panel on graduate funding opportunities and application experiences. This workshop introduced two important sources of funding for graduate students: the NSF Graduate Research Fellowship Program (GRFP), led by Ciara Garcia and Savannah Fuqua (BRIDGES cohort I student), and the Fulbright US Student Program, led by Pablo Aran (BRIDGES cohort I student). Students were also introduced to several additional funding sources from the University of Arizona and academic societies.

The last formal session of the institute was a workshop with Anne Mook, who led the pre-session. Students worked in teams on their portions of the final report with her guidance and that of Cohort I student, Zoe Jensen.

The institute concluded with a closed session for BRIDGES NRT leadership, BRIDGES cohorts, and ECGN GIDP students. The session went over what to expect in fall and included presentations of completion certificates for cohort II students.

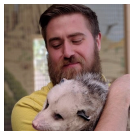
Conclusions and Future Directions

Students from the BRIDGES NRT second and third cohorts and year one ECGN GIPD students were immersed in a collaborative learning environment, exploring team science approaches to investigate challenges related to ecosystem genomics. Cohort II

presented results from their previous summer's research, and cohort III presented their plans for the upcoming summer, receiving feedback from their peers, faculty, and the science community attending the Convergence Institute. This open dialogue and constructive feedback allowed students and participants to integrate newly acquired interdisciplinary tools into their graduate training and summer research, preparing cohort II for their theses or dissertations and cohort III for next year's Convergence Institute. Students were able to redefine their questions, methodologies, and anticipated results for their upcoming research projects. Moreover, presentations enabled students to learn from each other and to build their interdisciplinary networks with other cohort members and participants from various disciplines and institutions, including the students from the Auburn NRT. Students from both universities discussed how they could aid in each others' research to form collaborative teams, taking advantage of each others' skill sets and experimental techniques, leveraging value from their two distinct but related foci on climate change and genomics.

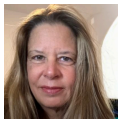
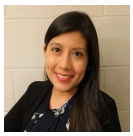
The institute tackled global challenges with an interdisciplinary approach that transcends traditional disciplinary perspectives, expanding the search for innovative solutions. It also prompted participants to consider the societal impacts of their research as well as the various cultures of science, with concrete examples of interdisciplinary barriers and the impact of the University of Arizona's Ecosystem Genomics initiative over the past year. Beyond the academics, the workshop fostered a sense of community among NRT trainees enrolled in different programs across two universities, empowering them to voice their opinions on current global scientific issues and provided them opportunities to further build their networks with visiting plenary panelists and University of Arizona faculty.

BRIDGES NRT and Auburn NRT Participants

 Sabrina Wilson University of Arizona Department of Hydrology and Atmospheric Science	Md Nafis Ul Alam University of Arizona School of Plant Science	 Neda Arad School of Plant Sciences
 Phoenix Spivey University of Arizona School of Natural Resources and the Environment	 Liam Roberts University of Arizona Entomology and Insect Science	 Harrison Friedman University of Arizona School of Natural Resources and the Environment
 Michael Keoki Spaeth School of Natural Resources and the Environment University of Arizona	 Sallu Nepal School of Plant Sciences University of Arizona	 Caitlin Tribelhorn Department of Environmental Science University of Arizona
 Poppy Northing Ecology and Evolutionary Biology University of Arizona	 Griffin Davis University of Arizona School of Plant Sciences	 Erica Cortez University of Arizona School of Plant Sciences
 Jhon del Aguila Pasquel Environmental Science University of Arizona	 Kieryn Zizzo University of Arizona School of Plant Sciences	 Michael Mustri Ecology and Evolutionary Biology University of Arizona

 Dakota Salyer University of Arizona School of Plant Sciences	 Ansleigh Bright, Department of Geosciences, Auburn University	 Antrelle Clark Department of Biological Sciences, Auburn University
 Erica Maul Department of Biological Sciences, Auburn University	 Steve McKnight Department of Political Science Auburn University	 Oliver Nell, Department of Agricultural Economics and Rural Sociology, Auburn University
 Katie Temple College of Forestry, Wildlife, and Environment Auburn University		

Organizers and panelists

 Scott Saleska University of Arizona	 Betsy Arnold University of Arizona	 Heather Ingram University of Arizona
 Zoe Jensen University of Arizona	 Patrick Sorenson Lawrence Berkeley National Lab	 Jana U'ren Washington State University
 Anne Mook Colorado State University	 Shirley Vincent, External Evaluator	 Jennifer Croissant University of Arizona
 Christine Beach University of Arizona	 Michelle Higgins University of Arizona	 Katie Brown Auburn University
 Viviana Friere Zapata Environmental Science University of Arizona	 Pablo Aran Ecology and Evo Biology University of Arizona	 Savannah Fuqua Ecology and Evolutionary Biology University of Arizona

 Ciara Garcia University of Arizona School of Plant Sciences		

Ecosystem Genomics in a Changing World

Name	Main findings
Savannah Fuqua Introduction	• Introduction to the “Ecosystem Genomics in a Changing World” presentation theme
Sabrina Wilson Parameterizing biochar effect on soil decomposition processes using integrated AI and process-based modeling	• Biochar addition can mitigate (promote) soil heterotrophic CO2 emission in soils with lower (higher) soil N contents. • The accumulated biochar addition effect consistently increases soil organic carbon across diverse sites. • Greater increase in SOC in areas with greater annual precipitation
Phoenix Spivey Impacts of Green Infrastructure: rainwater harvesting influence on soil health	• Rain garden treatments with more water inputs had chemical indicators (total Carbon and Nitrogen) that diverged from unaltered landscapes, implying that treatments improved soil properties important in semi-arid soil health, productivity, and fertility. • Seasonality influenced soil carbon and nitrogen extracellular enzymes differently. • Research shows that GI’s can harness water and drive important chemical and biological processes related to the cycling and storing of nutrients. These processes enhance semi-arid soil health and its ecosystem services needed to persist during climatic and anthropogenic changes.

Poppy Northing Evaluating the potential for rapid evolutionary response to climate: clues from the desert annual Pectocarya recurvata	• Sonoran Desert winter annual plants contribute greatly to southwestern biodiversity and are undergoing community compositional shifts due to climate change. • It is unclear whether these plants are evolving rapidly in response to novel selective pressures due to changing precipitation and temperature regimes. • This summer research will use one desert annual plant, Pectocarya recurvata, to tackle the question, “How might climate change be driving rapid evolution in winter annual plants in the Sonoran desert?” using three approaches: 1) Measuring traits in the field from populations spanning temperature and precipitation gradients, 2) Conducting a landscape genomics analysis to identify local adaptation, and 3) Measuring genotypic and phenotypic change across time using historical collections.
Jhon del Aguila Pasquel Metabolomic implications of methane dynamics in permafrost of Stordalen	• The increase in atmospheric methane is related to global wetlands. • Metabolomics is used to understand the role of microbes in the dynamics of the methane cycle in tropical and permafrost-related wetlands.
Michael Mustri Constraining metabolic reaction networks through thermodynamic optimization	• Plant carbon inputs drive soil microbial community composition and function. • Microbial metabolism is composed of chemical transformations with measurable thermodynamic properties. • Thermodynamic properties of microbial activity can be leveraged to create macroscopic models of ecosystem functions.

Key Takeaways from ‘Ecosystem Genomics in a Changing World’

Global climate change rapidly changes ecosystems' composition, dynamics, and function. While existing models predict the direction and magnitude of such climatic changes at large scales, anticipating how a given organism, community, or ecosystem will respond to these changes remains an ongoing challenge. Ecosystem Genomics is well-suited to approaching this challenge as an emerging interdisciplinary field to bridge genomics and ecosystem science to generate knowledge and solve pressing problems. Several BRIDGES NRT students’ research projects investigate how climate change impacts ecosystems. While they leverage various biological systems and methodologies

across different scales, these students share an understanding of how climate change affects ecosystems and their functioning.

On the first day of the Convergence Institute, five BRIDGES NRT students presented their summer research projects (proposed or completed), all characterized by their emphasis on “Ecosystem Genomics in a Changing World.” Sabrina Wilson (cohort II) presented her work on modeling the relationship between biochar and CO_2 emissions. Her models elucidate that the accumulated addition of biochar consistently increases soil organic carbon across diverse sites, and there is a greater increase in soil organic carbon in areas with more significant annual precipitation. Phoenix Spivey (cohort II) researched the benefits of green infrastructure and concluded from her summer research that rain gardens can improve soil properties in semi-arid regions. Poppy Northing (cohort III) studies how rapid evolution occurs in response to novel selective pressures posed by climate change in the Sonoran Desert winter annual plant community, using Pectocarya recurvata as a model system. Her summer research will use a combination of genomics and trait-based ecology to address this aim. Jhon del Aguila Pasquel (cohort III) investigates the role microbes play in the dynamics of the biogeochemical cycling of methane (an important greenhouse gas). He will use metabolomics in both tropical and permafrost wetlands to understand methane dynamics at the global scale. Michael Mustri (cohort III) is developing a macroscopic model of ecosystem functioning that leverages the thermodynamic properties of microbial activity.

These presentations showcase various disciplinary approaches, methodologies, and systems. At the same time, they also cover multiple biological and spatial scales—some study organisms or communities, while others study large-scale biogeochemical processes at the ecosystem level. Even within the “Ecosystem Genomics in a Changing World” topic, uniting themes exist between individuals with different disciplinary backgrounds. For example, Wilson (an atmospheric scientist) and Spivey (a soil scientist) both address the health of the environment through the evaluation of soil properties. Additionally, del Aguila Pasquel (a wetland microbial ecologist) and Mustri (an ecological modeler) both leverage metabolomics data from microbial communities to connect microbial processes to ecosystem functioning. Ultimately, while students employ different approaches, systems, and expertise in their research projects, each works towards connecting genes to ecosystem processes to understand climate change impacts.

Genomic/Genetic Controls, Arid-Land Organisms

Name	Main findings
Pablo Arán Introduction	• Introduction to the “Genomic/Genetic Controls, Arid-Land Organisms” presentation theme
MD Nafis ul Alam Collapsing inflated genome assemblies: an example with ocotillo	• The ocotillo genome assembly. • Necessity and utility of tools that standardize genome assemblies of varying quality, contiguity, and genome structure. • Newly developed methods for collapsing inflated genome assemblies.
Liam Roberts Searching for genes contributing to desiccation resistance in Drosophila mojavensis	• Identified genes involved in desiccation resistance that may be involved in adaptation to deserts in insects. • Intraspecific local adaptation using time series RNA-seq • Desiccation resistance phenotype for cactophilic Drosophila
Griffin Davis Using fungal herbarium specimens to unlock historical records of genetic diversity	• Endophytes are a snapshot in time, and incorporating them into biodiversity studies allows for a larger illustration of fungal biodiversity. • Macrofungi stored in herbarium collections should be molecularly characterized as they can show past fungal communities • We can then assess whether we have a loss of biodiversity by collecting and characterizing current collections • Emphasizing the effects of climate change on biological organisms
Kieryn Zizzo Identifying atoxigenic strains of Fusarium from wild relatives of crop plants	• Fusarium is an agriculturally devastating genus of plant pathogens present worldwide. • By analyzing the genomes of related endophytes from the same genus, we may identify a strain that could be a potential biocontrol for Fusarium and reduce mycotoxin production by the pathogenic strains.

Key takeaways from ‘Genomic/Genetic Controls, Arid-Land Organisms’:

The session highlighted the integration of genomics into studying organisms adapted to arid environments, revealing important ecological and evolutionary patterns. MD Nafis ul Alam and Liam Roberts both focused on the specific genomic adaptations in arid-land organisms, with Alam addressing technical aspects of genome assembly in ocotillo and Roberts identifying genes linked to desiccation resistance in Drosophila mojavensis. Alam’s work on standardizing genome assemblies provides a foundational tool that enhances the accuracy of genomic studies like those conducted by Roberts, who utilizes these advanced genomic techniques to explore adaptive traits in desert-adapted species. Griffin Davis plans to connect past and present biodiversity through the molecular characterization of fungal specimens stored in herbaria, assessing changes over time. This historical perspective complements the genetic adaptation studies presented by Roberts and Alam, offering a broader view of how species have historically adapted and might continue to adapt to changing arid environments. Kieryn Zizzo’s research on identifying toxigenic strains of Fusarium uses genomic tools to address agricultural problems posed by pathogenic fungi, which is an application of genomic insights that directly impact ecosystem health and farming practices. While focused on a different aspect of genomics, Zizzo's work ties back to the overarching theme of using genomic data to solve real-world problems, much like the other presenters. All presentations underscored the importance of genomic and genetic research in understanding and managing ecosystems, particularly those under stress from environmental changes. From Alam’s methodological advancements to Zizzo’s applied genomics in agriculture, the presentations painted a comprehensive picture of how genomic studies are pivotal in decoding the complexities of life in arid environments and using these insights to solve ecological and practical challenges.

The collection of research interests captured under the theme "Genomic/Genetic Controls, Arid-Land Organisms" highlights a comprehensive exploration of how unique genomic adaptations and ecological dynamics in arid environments can inform broader biological and conservation strategies. The research underscores the value of arid land organisms, which have evolved unique genomes that provide critical insights into survival and adaptation strategies—this is further emphasized through the study of macrofungi, which serve as historical markers of biodiversity and help assess changes over time due to climate impacts. Furthermore, the resilience of microbial communities to disturbances such as forest fires and grazing suggests a complex interplay between environmental stressors and microbial adaptation, which could influence future

conservation and restoration strategies. The emphasis on streamlined data integration from diverse sources also reflects a growing need to enhance research methodologies in genomics-centered ecological studies. This integration is crucial for advancing our understanding of environmental and genomic interactions, particularly in arid landscapes' unique and varying contexts where minor ecological shifts can have amplified effects.

Microbes, Microbiomes, and their Importance in Ecosystem Genomics

Name	Main findings
### Viviana Friere Zapata Introduction	• Introduction to the “Microbes, Microbiomes, and their Importance in Ecosystem Genomics” presentation theme
### Michael Spaeth Restoration through disturbance: impacts of grazing, controlled burns, and strip seeding on soil microbial communities	• Restoration techniques (grazing and burning) did not significantly influence soil bacterial communities. • Grazing significantly decreased soil fungal diversity. • Grazing and burning led to shifts in the composition of the soil microbial community, which has implications for soil function.
### Neda Arad Plant genotype as a determinant of microbial community composition in lettuce	• Variation in microbial composition among different lettuce cultivars correlates with genetically mediated phenotypic traits. • Leaf microbial diversity correlates with leaf chemistry. • Root microbial diversity aligns positively with root biomass and negatively with water content. • Certain lettuce varieties, such as Crisphead and Romaine, exhibit higher fungal richness and diversity, while bacterial richness and diversity are more pronounced

	in Red Leaf lettuce. These patterns highlight the complex interactions between lettuce genotypes and their microbial associates. ● Understanding endophytic microbial communities provides insights into improving lettuce cultivation practices and potential health benefits, given the interaction between plant microbiomes and the human gut.
Harrison Friedman (pre-recorded)Using Phyloseq and FAPROTAX to understand how Sonoran Desert soil microbial community composition and function respond to altered precipitation regimes	● The Santa Rita Rainfall Manipulation Experiment (RainMan in short) is a large collaboration between USDA and UofA to understand how Sonoran Desert microbial ecosystems might respond to changes in precipitation patterns in response to climate change. ● Relative to normal conditions, climate change may result in either smaller, but more frequent or larger, but less frequent rainfall events. ● Tested whether changes in frequency and magnitude of desiccation stress modified stress, growth, and resource acquisition tradeoffs to change the composition and functional potential of microbes. ● Concluded this was not the case and microbial communities are resilient to changes in rainfall conditions.
Erica Cortez How do soil borne bacteria influence seed survival and germination in a lowland tropical forest?	● Characterization of seed-associated endophytic bacteria within pioneer tree species and their association with a local diversity of these trees (whether they are beneficial or pathogenic).

	• Use established data to compare bacterial and fungal dynamics. Therefore, bacterial and fungal dynamics can contribute to Ecosystem Genomics by providing insights into their interactions, genomic mechanisms, and the coexistence of different microbial communities within a single ecosystem, such as a tropical forest. • Gain insights into how these endophytic bacteria and fungi interact and influence each other within pioneer tree seeds. • Main goal is to integrate bacteria into the Janzen-Connell hypothesis in the seed stage, shedding light on the intricate web of interactions in a highly diverse tropical forest.
### Dakota Salyer Volatilome comparison of aflatoxigenic A. flavus & AF36 prevail on four crop types	• Elucidated planned methods for comparison of VOCs headspaces of aflatoxigenic and biocontrol Aspergillus flavus strains on different crop types • Use GFP labeled Aspergillus to see competitive abilities of non-aflatoxigenic biocontrol and toxigenic Aspergillus in competition • Use metabolomics approach better to understand the competitive abilities of a registered biological control • Will provide information about the competitive abilities of an approved biological control, as well as aid in biomarker and future biocontrol development
### Sallu Nepal Aflatoxin biocontrol on Fumonisin contamination in Maize	• Proposed methods to study the interaction between a mycotoxigenic fungi and a biocontrol fungi • Understand if climate change has any impact on their co-occurrence.

	• Will help in understanding the dynamics of these fungi with plants and with each other and can act as a model to learn more about mycotoxigenic and biocontrol fungal interactions
Caitlin Tribelhorn Associated growth dynamics in sedimentary microbial communities	• Proposed how they will be characterizing the ecophysiology of anaerobic archaea in coastal sediment • Will use microbiome data across 14 timepoints to create correlation matrices of species interactions through different substrate amendments and abiotic conditions • Correlate multiple techniques to investigate microbial symbioses in sediment

Key takeaways from ‘Microbes, Microbiomes, and their Importance in Ecosystem Genomics’

The session "Microbes, Microbiomes, and their Importance in Ecosystem Genomics" provided deep insights into how microbial communities interact with and impact ecosystems, especially under different environmental stressors. Here’s a synthesis that connects the themes and findings from the various presentations: Michael Spaeth focused on how soil microbial communities respond to physical disturbances like grazing and controlled burns. His findings indicated that while bacterial communities remained stable, fungal diversity significantly decreased, suggesting differential resilience within the microbial communities to environmental stressors. Harrison Friedman explored how changes in precipitation patterns affect microbial communities in the Sonoran Desert. His research indicated that microbial communities are resilient to variations in rainfall, echoing some aspects of Spaeth's findings on resilience but in the context of climatic stress rather than physical disturbances. Neda Arad examined how different lettuce cultivars support distinct microbial communities, demonstrating that plant genetics significantly influence microbial assemblages. This directly connects with understanding the role of microbe-genotype interactions in crop resilience and agricultural productivity, which can be critical for biocontrol strategies and improving cultivation practices. Erica Cortez and Caitlin Tribelhorn presented how microbial communities contribute to broader ecosystem dynamics. Cortez's work with

seed-associated endophytes in tropical forests highlighted the complex interactions between microbes and plant health. At the same time, Tribelhorn's study on anaerobic archaea in sedimentary environments provided insights into microbial interactions under various abiotic conditions, emphasizing the ecological roles of microbes across different environments. Dakota Salyer and Sallu Nepal focused on pathogenic and biocontrol fungi dynamics. Salyer's work with aflatoxigenic and biocontrol strains of Aspergillus flavus on crops and Nepal's study on the interaction between mycotoxigenic fungi and biocontrol agents in maize highlighted the potential of using biocontrol strategies to manage crop pathogens effectively. These studies link closely with Neda Arad's findings on the genetic interactions with microbial communities, suggesting potential pathways for enhancing biocontrol approaches using genetic insights. These interconnected presentations demonstrated how microbial genomics could be applied to address critical questions in ecology, agriculture, and biocontrol, providing a rich tapestry of insights into the resilience, adaptation, and functional capabilities of microbial communities in various ecosystems.

This theme highlighted the diverse research on microbial communities and their significant role in Ecosystem Genomics. Microbes can answer many questions about an ecosystem when utilizing disciplines of ecology, microbial genetics, and integrating these domains to research an area of interest. Advancements in genomic technologies, such as high-throughput sequencing and metagenomics, have revolutionized the study of microbes and microbiomes. These tools enable researchers, such as the students of this Convergence Institute, to characterize microbial communities in unprecedented detail, uncovering the genetic and functional diversity that drives ecosystem processes. Integrating microbiome research with other ecological and genomic studies will be vital in addressing complex environmental challenges and harnessing microbial functions for sustainable development. Understanding these dynamics of microbes and their environmental impacts is essential for agricultural practices, ecosystem restoration, and future biocontrol methods.

Relevance of Convergence Research

The team science concept was an important theme at the Convergence Institute's forefront. Strategies for successful team science projects were shared with the group, followed by several interactive sessions in which group members discussed ways to achieve team science at the Convergence Institute. To further make the case for team science, many examples were provided of team science being associated with positive research outcomes, operationalized by grant dollars, publications, and continued collaboration. However, successful research does not end with a significant finding or a

peer-reviewed journal. While these are vital and exciting benchmarks within the research process, truly successful research must transcend academic boundaries and create an impact on the larger public. Extending research impacts beyond one's discipline typically involves partnerships outside academia, a sincere connection to society, and scientifically rigorous research. While this is true for all scientific endeavors, convergence science will benefit from having all three components. Through relevant research, convergence scientists might achieve any combination of impacts. Advancing instrumental and technical knowledge, expanding topic conceptualization, capacity building, making novel connections between fields, and broader socio-environmental impacts are just a few ways convergence science can create meaningful and positive change. This might be accomplished by enhancing citizen participation, focusing on literacy and knowledge dissemination, creating social and economic opportunities, and training new convergence scientists.

Future Directions

Short-term

The 2024 Convergence Institute fostered in-depth learning, not just about Ecosystem Genomics research but also professional development, collaboration, and broader impacts. Additionally, attendees established new connections and shared research ideas. The following is a list of new research questions shared by attendees working in multiple disciplines at the institute's culmination. In the near future, attendees may incorporate these new questions and concepts into their graduate research projects, working with new collaborators to integrate interdisciplinary approaches.

- How do micropollutants impact EEAs in green infrastructure?
- How would disturbances within urban environmental settings influence soil microbial communities' diversity and richness?
- How can I incorporate a plant community survey into my research since plants are an integral part of my biodiversity survey?
- How do foliar endophytes impact downstream soil decomposition?
- Do endophytes impact plant distribution?
- Is the level of disturbance studied not "disturbing enough" that it does not follow the established hypothesis curve?

- How can I incorporate metadata (e.g., pH) to understand the methane cycle in wetlands?
- How can I evaluate the metabolomics of microbes and their associated plants, and what are the best ways to assess how they impact each other?
- How can microbes influence plant defense against biotic and abiotic stress response? What pathways can be involved?

Mid-term

Looking Inward and Looking Forward

Ecosystem Genomics is, by definition, an innovative and transdisciplinary form of research. As such, to ensure the field's continued growth, it is necessary to develop best practices systems to overcome barriers related to communication, disciplinary norms, and varying professional priorities. As they work to build the field, researchers must also think critically about the research process and personal lessons they've learned. Recording these lessons and insights will be crucial to identifying best practices and developing replicable research procedures. As emphasized during the Convergence Institute, integrating relevant social science research will be necessary at this stage. Also, because impact is a value so central to Ecosystem Genomics, it is crucial for researchers, as they lay the foundation of the discipline, to focus on developing their research impact identities (as described in Michelle Higgins's Day 3 presentation). This will create a formidable culture of impact-thinking in the emerging field.

Addressing Global Challenges

Ecosystem Genomics aims to understand how microbial and genomic-scale biogeochemical systems inform the function of entire ecosystems and vice versa. As an emerging field, many of its mid-term priorities involve defining and developing its different parts, several of which were addressed at the Convergence Institute. Presentations discussed genomic-level impacts on greenhouse gas cycling and emissions reduction, the positive effects of green infrastructure on soil health, specific fungal communities' roles in large-scale agriculture, and the nature of rapid, climate-caused microevolution, among others. In the mid-term, researchers working in Ecosystem Genomics must continue to think innovatively about global, ecosystem-level issues and identify the new research areas necessary to address them.

Long-term

Branching Historically Distant Fields:

Framing question: What is the historical basis for forming academic disciplines, and how do these historical conceptions act as barriers or facilitators of current interdisciplinary practices?

For continued investigation based on the Cultures of Science:

- What are the conceptual distances between disciplines in the emerging field of Ecosystem Genomics, and how can existing barriers to interdisciplinary research and practice be overcome?
- How can we better understand these disciplinary barriers by leveraging knowledge about students' cultural backgrounds, perspectives, and worldviews?
- Are certain features or aspects of interdisciplinary research & practices incommensurable with others?
- How can we better understand scales across disciplines?
- How can we better understand and study field formation (network analysis, student-centered faculty networks, other)?

Defining and Evaluating Ecosystem Genomics as an Emerging Field

One student described Ecosystem Genomics as " … a major step towards understanding how our world is changing in the age of climate change …. I think it is the missing link to answering some major questions about the future."

Using this definition as a launchpad for further investigation, we ask the following questions:

- How is Ecosystem Genomics understood and described by faculty, students, or other institutional stakeholders?

- How do Ecosystems Genomics faculty and research students engage with interdisciplinary research and practice?
- How can scientists from different epistemological and philosophical traditions [i.e., ecosystems genomics and social scientists] work together to facilitate the integration of knowledge toward solving our common and most pressing global problems? [mid to long-term time scales]

Finally, we consider the following concerning an overarching goal of convergent science:

How can we gain knowledge about these practices with the goal of “a deeper level of work[ing] together that lets us ask new questions.”?

*(J. Cross, PhD, BRIDGES seminar, 2024)

Appendices

Appendix 1: Agenda

CONVERGENCE INSTITUTE AGENDA

Pre-session: Monday, May 13; CI: Tuesday, May 14, 2024 and Wednesday, May 15, 2024

PRE-SESSION (Monday, May 13)*

Day 0- 9:00am-5:00pm. Keating building, rm 103 (limited to registrants, in person)

9:00am-12:00pm

Interdisciplinary Team Science in Action, Anne Mook (Institute for Research on the Social Sciences, Colorado State University)

12:00pm - 12:45pm

Lunch

12:45pm - 2:00pm

Interdisciplinary Report Assignments and Team Contract, Anne Mook

Break- 5 min

2:05pm-3:05pm (open only to BRIDGES students and ECGN GIDP students)

Trainee Focus Group, Shirley Vincent (Owner and Consultant, Vincent Evaluation and Consulting)

Break- 5 min

3:10pm-4:50pm (open only to BRIDGES students and ECGN GIDP students

University of Arizona Responsible Conduct of Research Training (laptop required)

Dinner: NRT Trainees and Panelists

CONVERGENCE INSTITUTE (Tuesday, May 14- Wednesday, May 15)

Tuesday, May 14

Day One- 8:45am-4:30pm, Keating Building, rm 103

8:45am-9:00am

Check in

9:00am-9:30am

Welcome, Scott Saleska (Professor of Ecology and Evolutionary Biology, UA) and Betsy Arnold (Professor and Curator of the RL Gilbertson Mycological Herbarium, Plant Sciences, UA)

9:30am - 11:15pm

“Challenges of Ecosystem Genomics”: Keynote Panel and Discussion:

Team Science to Confront Challenges in Ecological Genomics, Patrick Sorenson (Project Scientist, Lawrence Berkeley National Laboratory)

Integrating fungal ecology and genomics with trace gas fluxes in Alaska, Jana U’Ren (Assistant Professor, Washington State University)

Break- 10 min

11:15am - 11:45am

Self-introduction by Guests from the Auburn University NRT in Climate Resilience

2:00pm-12:15pm

Group photo

12:15 pm-1:00 pm

Working lunch- Open science discussions

1:00pm - 4:30pm (open to all registrants/hybrid)

Trainee Research Engagement Presentations Parts I and II

1:00pm-2:50pm

Trainee Research Engagement Presentations, Part I

10-12 min presentation w/ Q&A, 20 min allotted

Theme: Ecosystem Genomics in a Changing World

Introduction, Savannah Fuqua (Ecology and Evolutionary Biology, UA)

Parameterizing Biochar Effect on Soil Decomposition Processes Using Integrated AI and Process Based Modeling, Sabrina Wilson (Hydrology and Atmospheric Science, UA)

Impacts of Green Infrastructure: Rainwater Harvesting Influence on Soil Health, Phoenix Spivey (School of Natural Resources and the Environment, UA)

Evaluating the potential for rapid evolutionary response to climate: clues from the desert annual Pectocarya recurvata, Poppy Northing (Ecology and Evolutionary Biology, UA)

Metabolomic implications of methane dynamics in permafrosts of Stordalen,

Jhon del Aguila Pasquel (Environmental Science, UA)

Constraining metabolic reaction networks through thermodynamic optimization,

Michael Mustri (Ecology and Evolutionary Biology, UA)

Break- 10 min

3:00pm-4:30pm

Trainee Research Engagement Presentations, Part II

10-12 min presentation w/ Q&A, 20 min allotted

Theme: Genomic/Genetic Controls, Arid-Land Organisms

Introduction, Pablo Arán (Ecology and Evolutionary Biology, UA)

Collapsing inflated genome assemblies: an example with ocotillo, MD Nafis Alam (School of Plant Sciences, UA)

Searching for genes contributing to desiccation resistance in Drosophila mojavensis,

Liam Roberts (Entomology and Insect Science, UA)

Using fungal herbarium specimens to unlock historical records of genetic diversity,

Griffin Davis (School of Plant Sciences, UA)

Identifying Atoxigenic Strains of Fusarium from Wild Relatives of Crop Plants, Kieryn Zizzo (School of Plant Sciences, UA)

Dinner: Caruso's Italian, 6pm

Wednesday, May 15

Day Two- 8:45am-5:00pm Keating Building, rm 103

8:45am - 11:30am

Trainee Research Engagement Presentations Part III

10-12 min presentation w/ Q&A, 20 min allotted

Theme: Microbes, Microbiomes, and their Importance in Ecosystem Genomics

Introduction, Viviana Friere Zapata (Environmental Science, UA)

Restoration through disturbance: impacts of grazing, controlled burns, and strip seeding on soil microbial communities, Michael Spaeth (School of Natural Resources, UA)

Plant Genotype as a Determinant of Microbial Community Composition in Lettuce, Neda Arad (School of Plant Sciences, UA)

Using Phyloseq and FAPROTAX to Understand How Sonoran Desert Soil Microbial Community Composition and Function Respond to Altered Precipitation Regimes, Harrison Friedman (School of Natural Resources, UA)

How do soilborne bacteria influence seed survival and germination in a lowland tropical forest?, Erica Cortez (Arizona Biological and Biomedical Sciences, UA)

Break- 10 min

Volatilome Comparison of Aflatoxigenic A. flavus & AF36 Prevail on Four Crop Types, Dakota Salyer (School of Plant Sciences, UA)

Aflatoxin Biocontrol on Fumonisin Contamination in Maize, Sallu Nepal (School of Plant Sciences, UA)

Associated growth dynamics in sedimentary microbial communities, Caitlin Tribelhorn (Environmental Science, UA)

Break- 10 min

11:40 am-12:20pm

Cultures of Science

Cultures of Science Report, Jennifer Croissant (Associate Professor of Gender & Women's Studies, UA) and Lived Experiences of BRIDGES Research Trainees: Interdisciplinary Practices and Perceived Barriers, Highlights, and Program Impact, Christine A. Beach (Higher Education, UA)

12:20 pm-1:00 pm (open to all registrants)

Lunch

1:00pm-4:15pm (Select from 2 tracks)

Track 1: NRT Faculty, Staff, and BRIDGES Advisory Board

1:00pm-2:00pm

NRT Faculty Focus Group Discussion with Shirley Vincent (Owner and Consultant, Vincent Evaluation and Consulting)- Keating Room 103

Break- 5 min

2:05 pm-3:05pm

Progress and Recruitment Report, Betsy Arnold (Professor and Curator of the RLG Mycological Herbarium, Plant Sciences, UA), Scott Saleska (Professor of Ecology and Evolutionary Biology, UA), and Heather Ingram (Assistant Director, BRIDGES NSF Research Traineeship Program, UA)- Keating Room 103.

Break- 5 min

3:10pm-4:10pm

Evaluation Report, Shirley Vincent (Owner and Consultant, Vincent Evaluation and Consulting)-Keating Room 103

Track 2: NRT Trainees, AU Trainees, UA Community

1:00pm -1:55pm

What is the Impact of your Research on Society?, Michelle Higgins (Associate Director, Office of Societal Impact, UA)

Break- 5 min

2:00 pm-2:40 pm

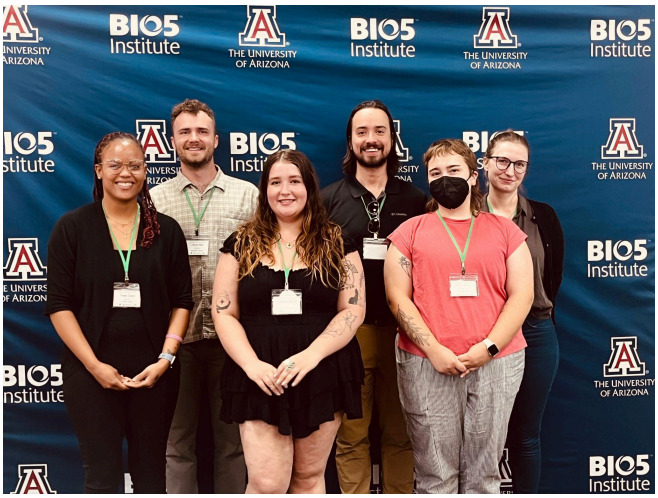
GRFP and Fulbright Funding Opportunities, Savannah Fuqua (Ecology and Evolutionary Biology, UA); Ciara Garcia (School of Plant Sciences, UA); and Pablo Arán (Ecology and Evolutionary Biology, UA).

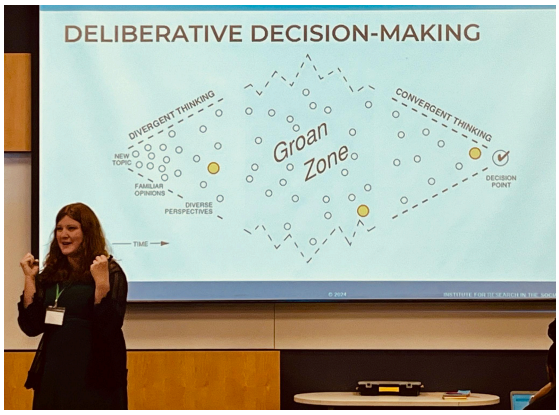
2:45pm-4:10pm

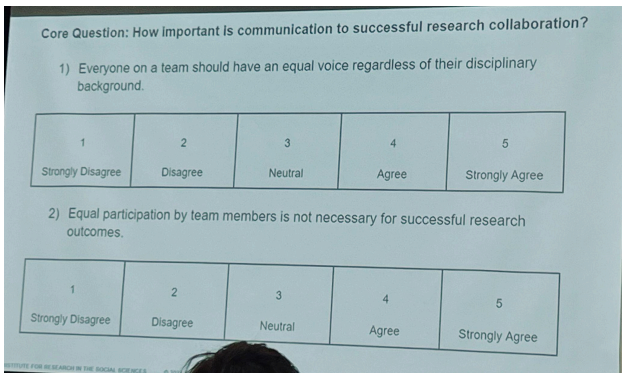
Convergence Institute Report Wrap-up, Anne Mook (Institute for Research on the Social Sciences, Colorado State University.

4:15pm-4:45pm
Trainee Next Steps, Scott Saleska, Betsy Arnold, and Heather Ingram- Keating Room 103

Appendix 2: Pictures from Convergence Institute









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